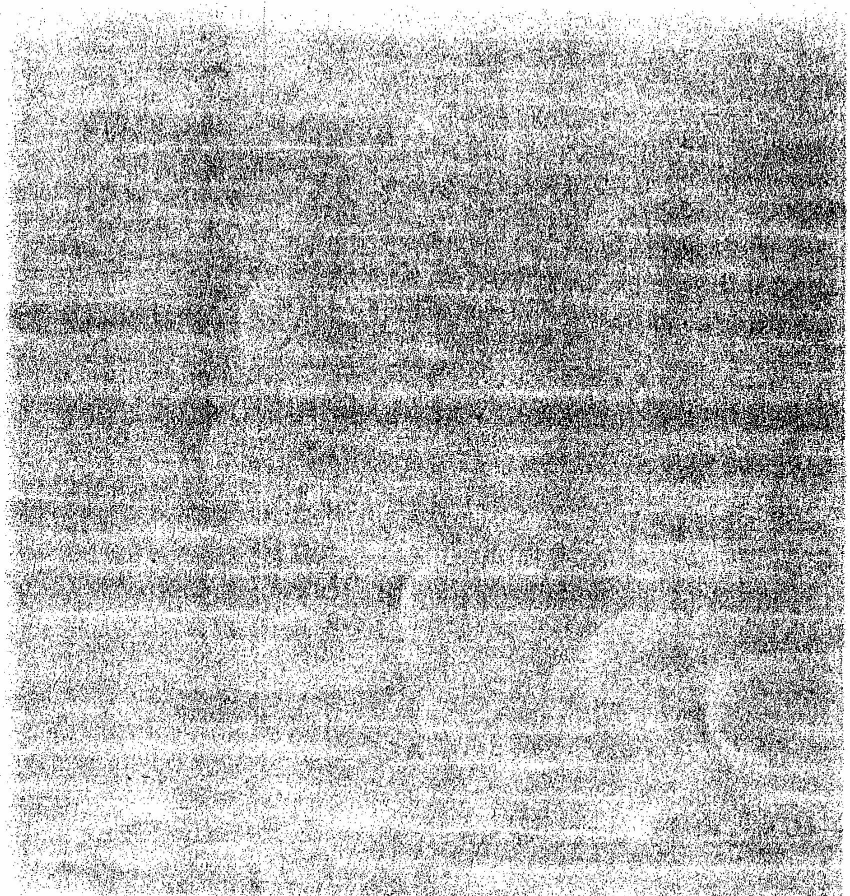
Cedar Lake T by 2000 Feasibility Study

—Final—



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June 1991

CEDAR LAKE ENHANCEMENT STUDY

- Final Report -

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SUMMARY

Cedar Lake is a 316 hectare (781 acre) kettle lake located in Lake County in northwestern Indiana. The lake is shallow with a maximum depth of only 4.9 meters (16 feet) and a mean depth of 2.7 meters (8.8 feet). Because Cedar Lake is situated on a topographic divide, its drainage area is small. This provides for limited runoff and a slow hydraulic flushing rate of 1.3 years.

Cedar Lake has been a popular resort area since the early 1900s. High density residential shoreline development with inadequate on-site septic systems was the major source of nutrient enrichment to Cedar Lake until 1977, when a wastewater collection system was constructed. Because of previous nutrient enrichment, Cedar Lake has been one of the most eutrophic lakes in Indiana. The IDEM trophic state index (TSI) for the lake in the mid-1970s was 70 out of 75 possible points.

Since the discontinuation of on-site septic systems Cedar Lake's water quality has slowly improved. While Cedar Lake is still classified as eutrophic, the lake's TSI has improved 22 points to 48 points. Water quality in Cedar Lake is characterized by dense blue-green algae blooms and poor transparency, caused by the plankton and by resuspension of sediments from wind and motor boats. Serious shoreline erosion contributes to transparency problems and to sedimentation in the already shallow lake.

Watershed modeling using the Agricultural Nonpoint Source model (AGNPS) has identified some watershed areas where nonpoint source controls are needed; however, the relatively flat slopes in the watershed minimize the delivery of nutrients and sediments to the lake. Approximately one-half of Cedar Lake's watershed drains through Cedar Lake Marsh which helps filter out nutrients and sediments that otherwise might be discharged into the lake. Additional studies of the wetland demonstrated that while some areas of Cedar Lake Marsh are saturated with nutrients, most areas have additional capacity to act as nutrient and sediment filters.

Recommendations for enhancing the water quality of Cedar Lake include:

1. Applying agricultural best management practices where needed.
2. Enhancing Cedar Lake Marsh's filtering ability by removing old wetland drains and rerouting flow more evenly through the wetland.
3. Correction of the wastewater system surging and overflows.
4. Applying urban best management practices where needed.
5. Implementation of an urban erosion and stormwater control ordinance.
6. Use of lakeshore erosion controls and aquatic vegetation plantings to reduce waves and protect shorelines.

7. Implementation of motor boat speed zones to further reduce wave generation and damage near the shoreline.

8. Rerouting Hogpen Ditch drainage into Cedar Lake with appropriate pretreatment to increase the lake's hydraulic flushing rate.

9. Repair of the lake's outlet structure and installation of a fish barrier.

10. A comprehensive carp management program to reduce turbidity and to protect vegetation plantings from these fish.

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ACKNOWLEDGEMENTS

Funding for this study was made available by a grant to the Cedar Lake Chamber of Commerce from the T by 2000 Lake Enhancement Program of the Indiana Department of Natural Resources, Division of Soil Conservation and Cedar Lake local contributions. We are indebted to the following members of the Lake Enhancement Committee of the Cedar Lake Chamber of Commerce for their assistance and support during this study: Jim Kubal (Chair), Dick Mickey, Terry Coffin, Bob Howkinson, and Guy Carlson.

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1.0 INTRODUCTION

This study is part of a continuing effort to improve water quality conditions within Cedar Lake. Efforts to date include:

1. Construction of a wastewater collection system to replace on-site septic systems within the town of Cedar Lake. Construction began in 1975 and most hook-ups were completed during 1977.

2. A 1979, state-funded study to investigate the feasibility of restoring Cedar Lake. This study was conducted by Indiana University's School of Public and Environmental Affairs.

3. A 1982 study, funded by the U.S. Environmental Protection Agency's Clean Lakes Program to provide additional information so that the 1979 study could qualify as a Phase I Diagnostic/Feasibility Study under EPA's program.

Recommendations contained in the completed Phase I Study could not be implemented due to lack of funds at both the local and federal levels. The reauthorization of the federal Clean Lakes Program in 1987, along with the creation of the Lake Enhancement Program within the Indiana Department of Natural Resources Division of Soil Conservation in 1987, provided the long-awaited opportunity for funding an implementation program at Cedar Lake.

The purpose of the present study is to satisfy additional requirements of the U.S. EPA Clean Lakes Program and to complete the feasibility study requirements of the Lake Enhancement Program. With the successful completion of these requirements, Cedar Lake will become eligible for design and implementation grants from both programs.

While portions of the original Phase I report entitled, "Cedar Lake Restoration Feasibility Study" (published in 1984) are duplicated in the present report to provide continuity, the reader is referred to the Phase I Study for more detail. Copies of the 1984 report are available and will be included with each copy of the present report.

CHAPTER 2: LAKE SETTING

2.0 LOCATION

Cedar lake located in west central Lake County, T34N, R9W, Sections 22, 23, 26, 27, 34 and 35. It lies approximately 4.5 miles southwest of Crown Point and forty miles southeast of Chicago. U.S. Route 41 (Wicker Street), Lake Shore Drive and Parrish Street, 133rd Avenue, Morse Street, and Cline Avenue provide the principal automobile access to Cedar Lake (Figure 2-1).

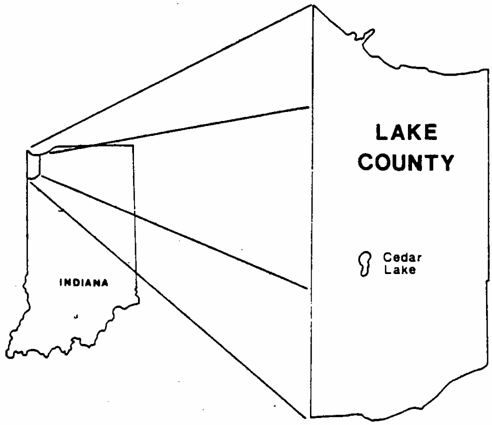


Figure 2-1. Location map.

2.1 LAKE MORPHOMETRY

Cedar Lake has a three-lobed shape that can be seen on the bathymetric map presented as Figure 2-2. The following morphometric parameters have been determined from the map:

Maximum Length	3.4 kilometers (2.1 miles)
Maximum Width	1.5 kilometers (0.9 miles)
Surface Area	316 hectares (781 acres)
Volume	$8.44 \times 10^6 m^3$ (6841 acre feet)
Maximum Depth	4.9 meters (16 feet)
Mean Depth	2.7 meters (8.8 feet)
Shore Line	9.5 kilometers (5.9 miles)
Shoreline Development Ratio	1.52

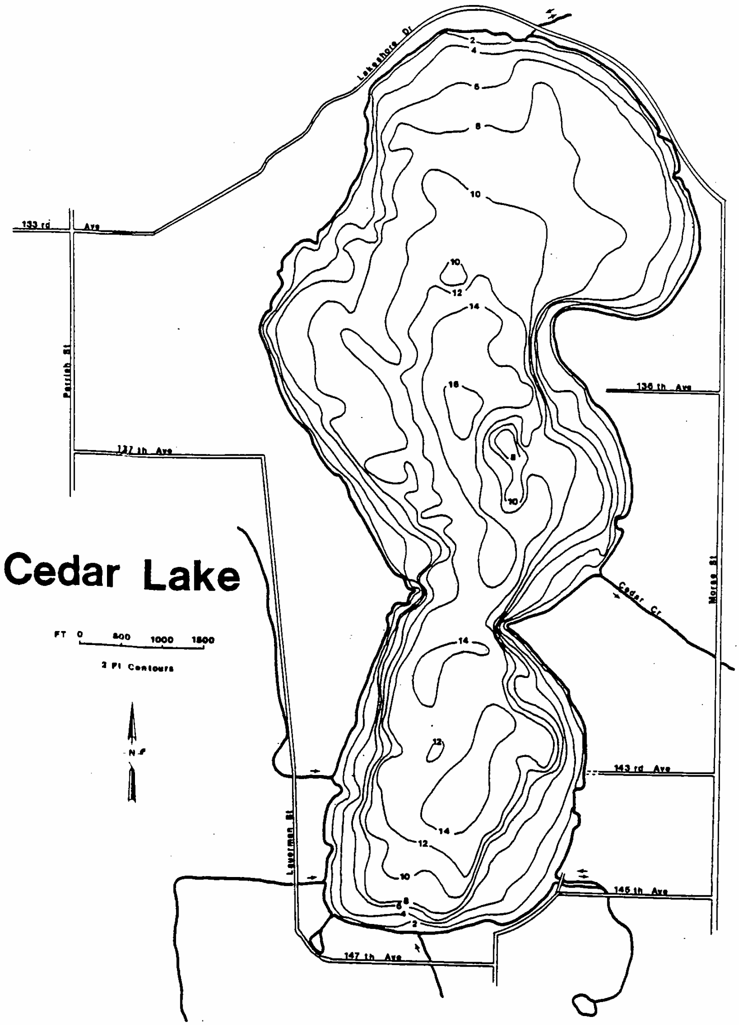


Figure 2-2. Bathymetric map.

The maximum length of Cedar Lake occurs along the north-south axis and the maximum width across the north basin. The maximum depth occurs in the middle basin. A hypsograph, which graphically represents the relationship between the surface area of a lake and its depth, is presented in Figure 2-3.

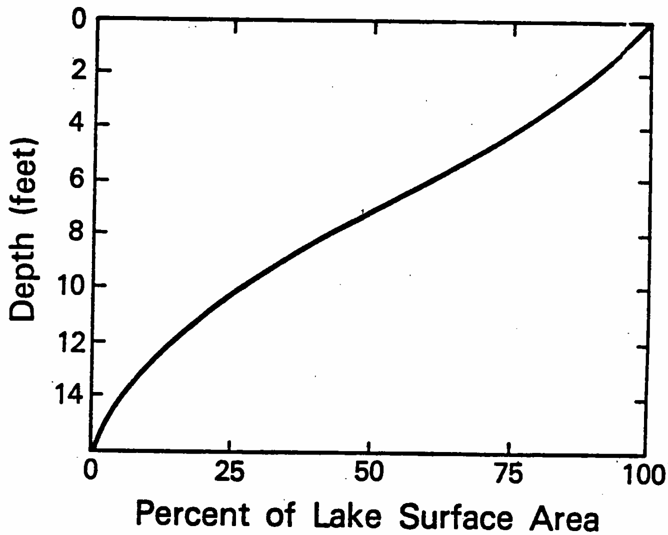


Figure 2-3. Hypsograph of surface area to depth relationship.

The graph illustrates a nearly linear relationship between percent area and depth for most of Cedar Lake except in the extreme shallows and deep areas, where there is slightly less relative area. This indicates that while Cedar Lake is shallow for its size, there is a rather even distribution between shallow and deeper waters.

Shoreline development is a ratio of the length of the shoreline to the length of the circumference of a circle of area equal to that of the lake. Very circular lakes approach the value of 1.0 while more elongated lakes have values exceeding 2 or 3. The value of 1.52 for Cedar Lake suggests that the shoreline is not overly convoluted due to bays or inlets.

2.2 DRAINAGE BASIN SIZE AND CHARACTERISTICS

Cedar Lake drains an area of approximately 4,837 acres (1951 ha) in size exclusive of the lake area itself (Figure 2-4). This area is larger than that reported in the Phase I Report because drainage alterations now allow th

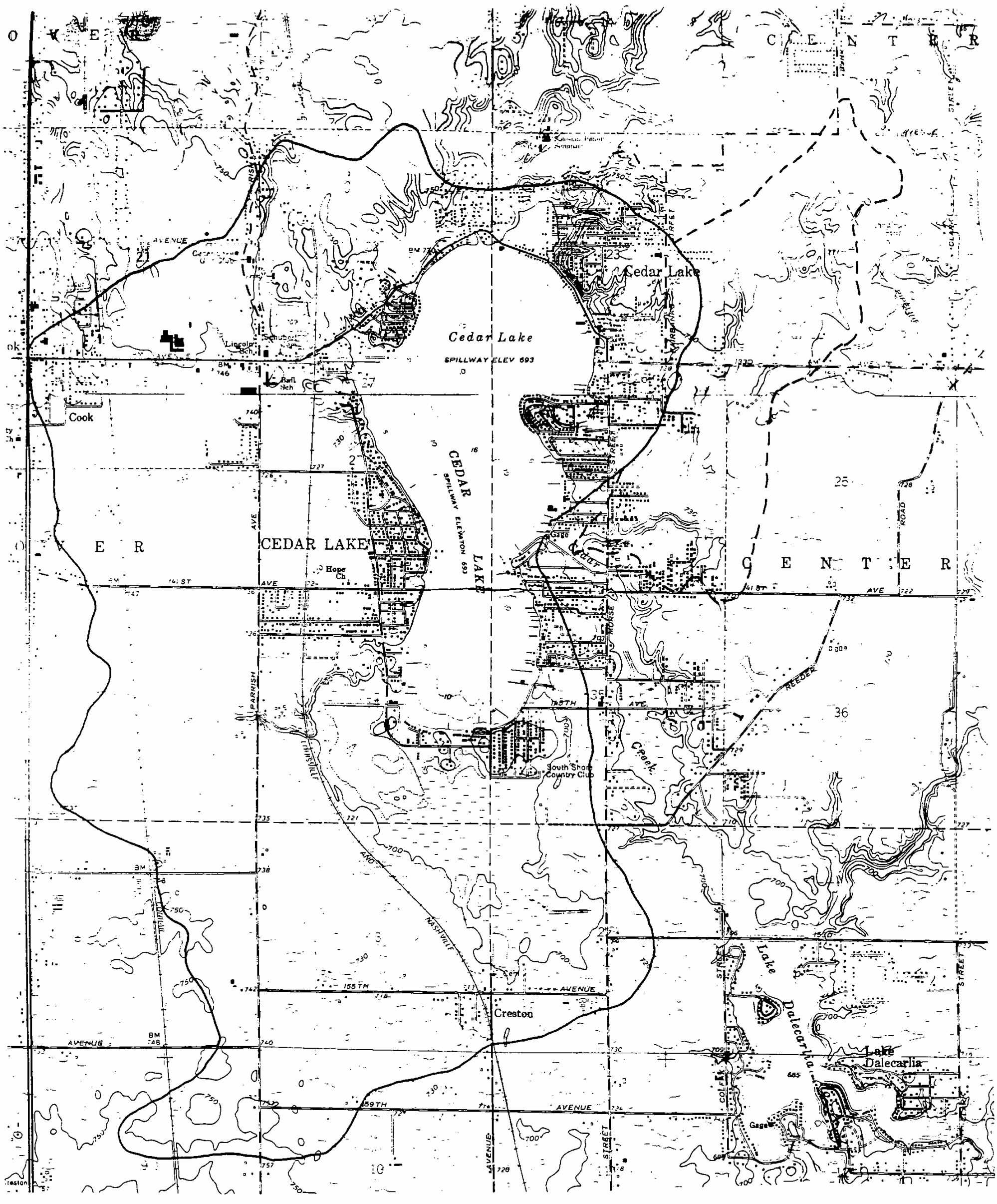


Figure 2-4. Cedar Lake drainage basin.

Shubert Lake area to drain into Cedar Lake. Within the watershed there are six streams, all of which cease to flow during dry periods. Three of these are considered inlets. In the past, Sleepy Hollow Ditch, an inlet at the west size of the lake, maintained flow over the entire year due to the effluent it received from the wastewater treatment plant for the Utopia subdivision which operated from 1956 to 1977. The two inlets on the south and southwest side drain a large 403 acre (163 ha) wetland, which, in turn drains approximately one-half of the drainage basin.

A stream on the southeast side connects Cedar Lake to a small golf course irrigation pond. Another stream at the northern end of the lake drains a small 14 acre (5.7 ha) wetland. Water in both of these streams has been observed to flow both into and out of the lake, depending on the season. When it does occur, streamflow is rather limited.

Cedar Creek, located on the east side of the middle basin, is the only outlet to Cedar Lake. This creek is also an intermittent stream and generally has no flow during the summer months. The location and ephemeral nature of the streams associated with Cedar Lake provide for only limited hydraulic flushing.

2.3 LAND USE

Classes of land use are found in the following percentages within Cedar Lake's drainage basin: 4% forest lands, 9% wetlands, 24% urban lands, and 63% agricultural and open lands. The distribution of lane use classes within the basin is illustrated in Figure 2-5.

2.4 PUBLIC ACCESS

Public access to Cedar Lake is available via a one acre property at the north end of the lake. The site is owned by the State of Indiana, leased to the town of Cedar Lake and managed by the Cedar Lake Chamber of Commerce. Facilities include a concrete boat ramp and gravel parking for approximately 20 vehicles with trailers. The boat ramp was re-built in 1988 by the Indiana Department of Natural Resources. Restroom facilities are available at the Chamber of Commerce building adjacent to the parking lot.

Additional public access to Cedar Lake are at:

1. Cedar Lake Town Hall - 17.3 acres on east side of the lake with picnic and recreational facilities and a swimming pool.

2. Cedar Acres Subdivision - 0.4 undeveloped acres.

3. Northeast Park - 0.3 undeveloped acres along Lake Shore Drive on the northeast edge of the lake.

4. Lake Shore Drive Park - 4.0 undeveloped acres on the northwest edge of the lake.

While these sites provide physical access to the lake, they do not have swimming areas or boat launches.

Additional boat launching ramps are available for a fee at three marinas on the lake. One marina maintains a public swimming beach, also available for a modest fee. There are no free, public beaches along Cedar Lake.

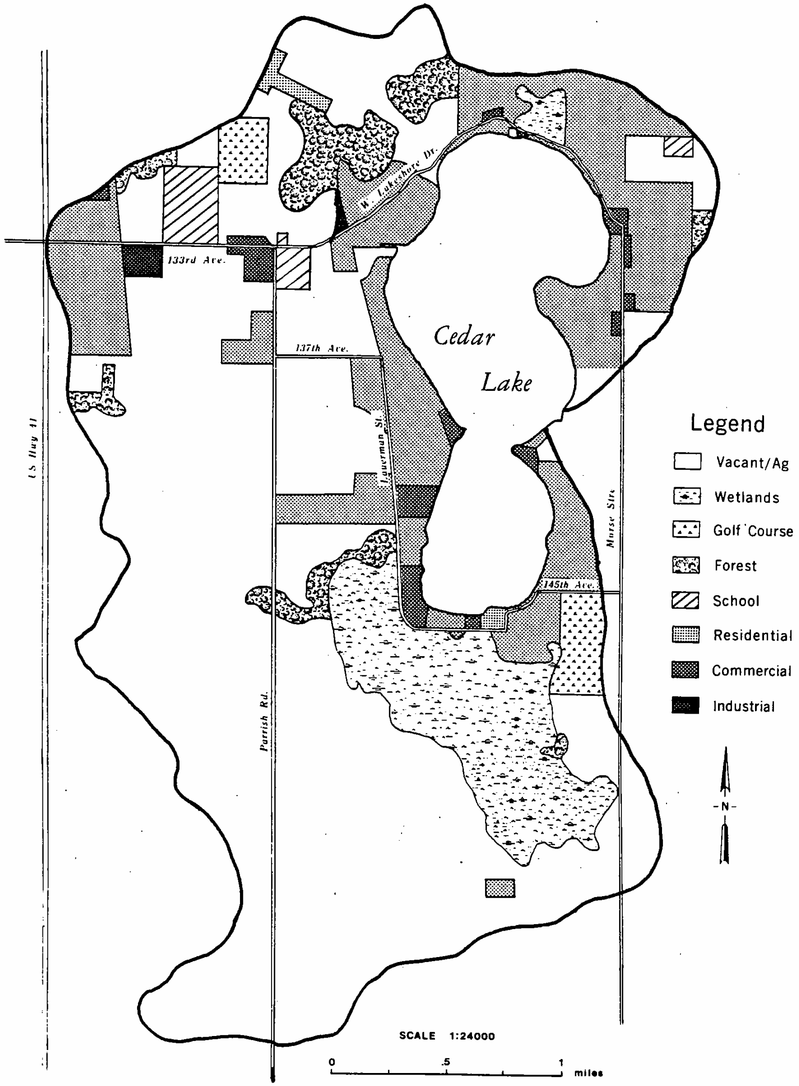


Figure 2-5. Distribution of land use classes in Cedar Lake's watershed.

3.0 LAKE QUALITY

3.1 WATER QUALITY

3.1.1 Methods

Water samples were collected from the depths over the deepest part of Cedar Lake on 8-21-89. Samples were collected from one meter below the surface (epilimnion) and one meter off the bottom (hypolimnion). Collected samples were all analyzed according to the 16th edition of <u>Standard Methods</u>, (APHA, 1985). In addition, dissolved oxygen and temperature measurements were made at one meter intervals, light transmission data were collected using a Secchi disk and a light meter. A plankton tow was taken of the entire water column, since the lake was totally mixed. Therefore, we considered the single tow representative of the epilimnetic and thermocline tows as specified by the IDEM trophic state index procedure (see Table 3-3).

3.1.2 Results

The water quality data displayed in Table 3-1 and Figure 3-1 show that Cedar Lake does not stratify. The shallow depth, long wind fetch and boat traffic all contribute to keeping the water well-mixed. Because of this, there is little change in temperature or oxygen with depth, nor is there much change between surface and bottom samples for the other parameters listed in Table 3-1. Total phosphorus (TP) and organic nitrogen concentrations are characteristic of over-productive, or eutrophic lakes. However, both of these parameters are significantly lower than TP (0.33 mg/l) and organic N (2.1 mg/l) concentrations recorded for the same period during 1979 (see Phase I Report).

Nitrate-nitrogen concentrations were much higher than ammonia-nitrogen concentrations. This is typical of well-mixed systems where the oxidized nitrogen dominates the reduced ammonia. Nitrate concentrations are much higher than those recorded during 1979, 1.14 in 1989 mg/l vs. 0.04 mg/l in 1979 for epilimnetic samples.

In 1979, plankton production was so excessive that nearly all inorganic nitrogen was consumed, leaving the lake somewhat nitrogen limited. Inorganic N vs. inorganic P ratios were 8.8:1 in August, 1979 but were 200:1 during August, 1989. Total nitrogen vs. total phosphorus ratios were 18.6:1 in August, 1979 and 63:1 in 1989. From this, we would expect to find lower phytoplankton concentrations in 1989.

Phytoplankton concentrations in the epilimnion were 491,279 cells/L in 1989 (Tables 3-1 and 3-2) but nearly 15,000,000 cells/L in 1979. The plankton were dominated by blue-green algae (99% by number) in both years. Blue-greens are considered to be nuisance species as compared to green algae or diatoms.

TABLE 3-1. WATER QUALITY DATA - 1989

PARAMETER	EPILIMNION	HYPOLIMNION	MEAN	EUTROPHY POINTS
Total P (mg/l)	0.055	0.044	0.05	2
SRP (mg/l)	0.01	0	0.01	0
NO3 (mg/l)	1.14	2.78	1.96	3
NH4 (mg/l)	0.05	0.05	0.05	0
Org-N (mg/l)	1.05	1.25	1.15	3
pH	9.6	9.5	-	-
Conductivity (umhos)	310	310	310	-
Alk (mg CaCO3)	106	108	107	-
Secchi (ft)	0.8			6
D.O. (% sat)	100			0
D.O. (% oxic)	100			0
Light Transmission at 3 ft	1 %			4
Plankton Surface tow	491,279 cells/L			10
bl-gr dominance	yes			5
Thermocline tow	491,279 cells/L			10
bl-gr dominance	yes			5

TOTAL POINTS 48

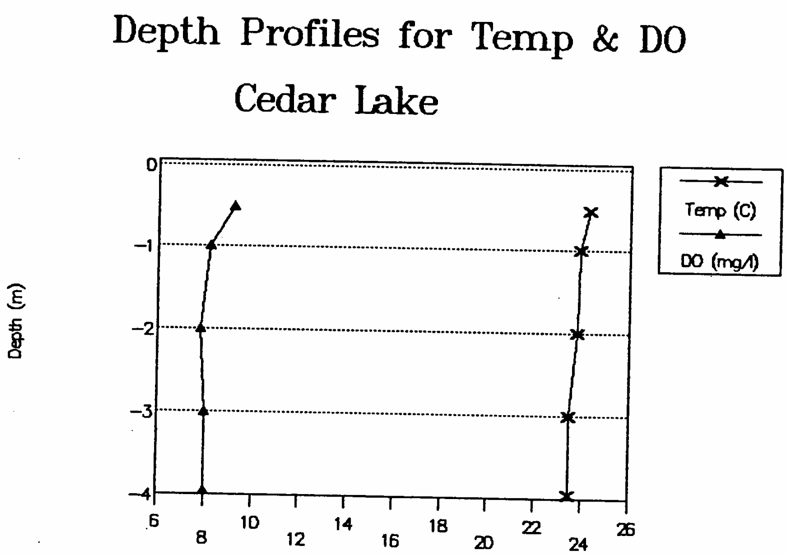


Figure 3-1. Temperature and dissolved oxygen profiles for Cedar Lake.

TABLE 3-2. Plankton Species Composition in Cedar Lake on 8-21-89.

SPECIES	ABUNDANCE (#/1)
<u>Blue-Green Algae (Phylum: Cyanophyta)</u>	
Anabaena	417
Coelosphaerium	1,668
Spirulina	417
Microcystis	487,098
<u>Green Algae (Phylum: Chlorophyta)</u>	
Pediastrum	417
<u>Diatoms (Phylum: Chrysophyta; Class: Bacillariophyceae)</u>	
Stephanodiscus	1,251
<u>Rotifers (Phylum: Rotifera)</u>	
Polyarthra	11

3.1.3 Trophic State Index

Water quality data collected were used in the Indiana Department of Environmental Management's (IDEM) trophic state index (TSI) (Table 3-3). A TSI is a numerical index representing a lake's eutrophication or productivity status. The IDEM TSI ranges from 0 (highest quality) to 75 (worst quality). Results (Table 3-1) show that Cedar Lake scored 48 eutrophy points. The last time Cedar Lake's TSI was calculated was the mid-1970's when the lake scored 70 points, almost the maximum number allowed. Since that time, water quality conditions, as reflected by the TSI parameters, improved 22 eutrophy points. Because of natural variability in lake conditions, a change of 10 points is necessary before one can conclude that a significant change has occurred. Therefore, the 22 point change indicates that water quality conditions have indeed improved since the mid-1970s. The TSI improvement reflects the water quality improvements discussed in the previous section.

TABLE 3-3

CALCULATION OF THE IDEM LAKE TROPHIC STATE INDEX

Parameter and Range			Eutrophy Points
I.	Total Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
II.	Soluble Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
III.	Organic Nitrogen (ppm)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
V.	Ammonia (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3
	D.	1.0 or more	4
VI.	Dissolved Oxygen		
		Percent Saturation at 5 feet from surface	
	A.	114% or less	0
	B.	115% 50 119%	1
	C.	120% to 129%	2
	D.	130% to 149%	3
	E.	150% or more	4

TABLE 3-3 (continued)

VII.	Dissolved Oxygen	
	Percent of measured water column with at lease 0.1 ppm dissolved oxygen	
A.	28% or less	4
B.	29% to 49%	3
C.	50% to 65%	2
D.	66% to 75%	1
E.	76% 100%	0
VIII.	Light Penetration (Secchi Disk)	
A.	Five feet or under	6
IX.	Light Transmission (Photocell)	
	Percent of light transmission at a depth of 3 feet	
A.	0 to 30%	4
B.	31% to 50%	3
C.	51% to 70%	2
D.	71% and up	0
X.	Total Plankton per liter of water sampled:	
	<u>One vertical tow from a depth of 5 feet</u>	
A.	Less than 4,700/L	0
B.	4,700/L - 9,500/L	1
C.	9,500/L - 19,000/L	2
D.	19,000/L - 28,000/L	3
E.	28,000/L - 57,000/L	4
F.	57,000/L - 95,000/L	5
G.	More than 95,000/L	10
H.	Blue-green dominance	5 additional points
	<u>One vertical tow from a depth of 5 feet that includes the beginning of the thermocline</u>	
A.	Less than 9,500/L	0
B.	9,500/L - 19,000/L	1
C.	19,000/L - 47,000/L	2
D.	47,000/L - 95,000/L	3
E.	95,000/L - 190,000/L	4
F.	190,000/L - 285,000/L	5
G.	285,000/L or more	10
H.	Blue-green dominance	5 additional points
I.	Population of 950,000/L or more	5 additional points

3.2 TOXICS MONITORING

On July 9, 1987, the Indiana Department of Environmental Management collected fish and sediment samples from Cedar Lake for the analysis of toxic compounds. Sediment grab samples were collected from the north and south basins of the lake. Each was analyzed separately. Three sets of fish composites were also analyzed. These included three carp fillets with skin off, three carp fillets with skin on, and three whole channel catfish.

Of the 23 inorganic metals and 152 pesticides and organic compounds tested for, none of the samples exceeded the U.S. Food and Drug Agency action levels for consumption. While these compounds were sometimes detected in the samples, the concentrations were too low to be concerned about. For example, although the carp fillets with skin on had the highest PCB concentrations, 0.17 mg/kg or ppm, this is far less than the US FDA action level of 2.0 mg/kg. Since many of these compounds are ubiquitous in the environment, it is not uncommon to detect them in low quantities in samples.

3.3 FISHERIES

Cedar Lake's fish population has a long history of being dominated by undesirable species. Efforts to renovate the lake's fishery have been unsuccessful due to the shallow water, high nutrients and turbidity, and the invasion of undesirable fish species from downstream areas.

On June 15-18, 1987, the Indiana Department of Natural Resources (IDNR) conducted a fishery survey using electrofishing, traps and gillnets (See Appendix A). Results of the survey show that sport fish only made up 64% of the total fish population by number and 29% by weight (Robertson, 1987). Carp accounted for 63% of the weight of all fish collected (Table 3-4).

The 1987 Fish Management Report (Robertson, 1987) recommends that "To successfully improve fishing at Cedar Lake, more than fish eradication and restocking needs to occur. Improvements in water quality through the permanent reduction of nutrients in the water column should be accomplished before another fish eradication is attempted. In addition, the fish population of Cedar Lake and/or Lake Dalecarlia must be permanently separated from fish populations in downstream Cedar Creek."

In an attempt to improve fishing opportunities, the Cedar Lake Chamber of Commerce stocked 4,400 hybrid striped bass in August 1987. The IDNR stocked an additional 7,935 hybrid striped bass on June 22, 1989 (Robertson, 1990). A follow-up IDNR survey on October 2-3, 1989 did not find any two year old hybrids from the 1987 stocking however, survival and growth of hybrids stocked in 1989 was good.

In June of 1990, IDNR stocked 16,000 hybrid striped bass and in October of that year, the Cedar Lake Chamber of Commerce stocked 8,000 hybrid bluegill and 3,000 largemouth bass.

On September 10-11, 1990 IDNR conducted a spot check to monitor growth and survival of hybrid striped bass stocked in 1987, 1989, and 1990. They collected 47 hybrids in four lifts. Young-of-year and I+ fish were found. Also collected in the 566 fish sample were 429 yellow perch, 60 carp, and 20 goldfish. Black crappie, white crappie, pumpkinseed, bowfin, and channel catfish were also found. No gizzard shad were found in the 1990 sample.

TABLE 3-4.

RESULTS OF 1987 FISHERY SURVEY

Species	Relative Abundance by Number (%)	Relative Abundance by Weight (%)
Yellow Perch	39	13
Carp	26	63
Black Crappie	13	4
Bluegill	9	4
Channel Catfish	2	5
Others	11	11

4.0 POLLUTION SOURCES

4.1 OVERVIEW

A specific goal of this study was to investigate more closely, existing and potential sources of pollution. Pollution entering lakes can be divided into two broad types: point and non-point. Point source pollution can be thought of as that which comes from a discrete point, for example a discharge pipe. Point sources are relatively easy to identify and are often regulated by state and federal statutes. Non-point sources are diffuse in nature. NPS pollution includes runoff from agricultural lands and parking lots, erosion from construction sites, etc. The U.S. Environmental Protection Agency (1989) estimates that 76% of all pollution to lakes in the U.S. is of non-point origin.

4.2 POINT SOURCES

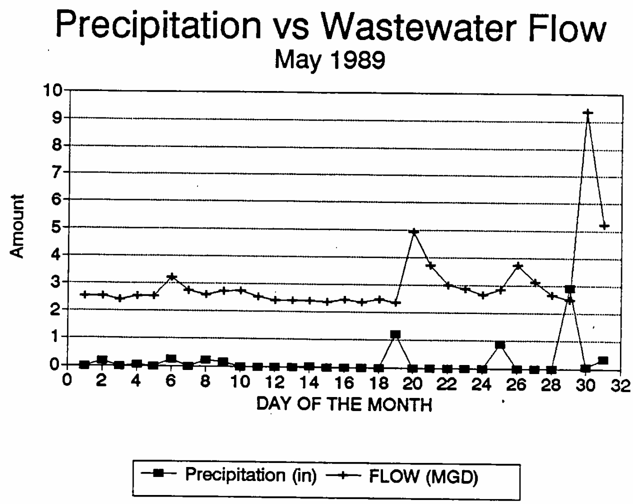
There are two known sources of point source pollution to Cedar Lake. The first of these are a pair of culverts at the northwest side of Cedar Lake. These culverts facilitate surface drainage from the intersection of Morse St. and 133 Avenue. While this is a relatively small area, and inputs of nutrients, suspended solids and petroleum products would likely be small relative to all inputs to Cedar Lake, these inputs could be reduced by implementing rather modest management practices (See section).

A second point source of pollution to Cedar Lake is caused by wastewater discharge from manhole covers (especially one on Lauerman St. at the southwest corner of the lake) during high wastewater flow periods. These periods are closely correlated with rainfall events. Peak wastewater flow in the collection system, which is routed to the Lowell WWTF, appears to lag behind rainfall events by about one day (Figure 4-1). The extra flow may result from infiltration or from suspected household foundation drains in the Utopia Subdivision and elsewhere which are connected to the wastewater collection system. The consulting engineer for the Town of Cedar Lake estimates that a sewer system evaluation to identify the sources of infiltration could cost upwards to $100,000 (P. Haas, 1989 pers. comm).

During 1989, two incidents of wastewater flow from manholes were reported following heavy rains. When these flows occur, raw sewage flows into Cedar Lake. It is not possible to estimate the volume of wastewater flow from manholes during these events, so the impact of these events on water quality in the lake cannot be determined.

4.3 NONPOINT SOURCES

Nonpoint sources of pollution to Cedar Lake can be lumped into three groups, shoreline erosion and septic system effluent specifically, and watershed sources generally.



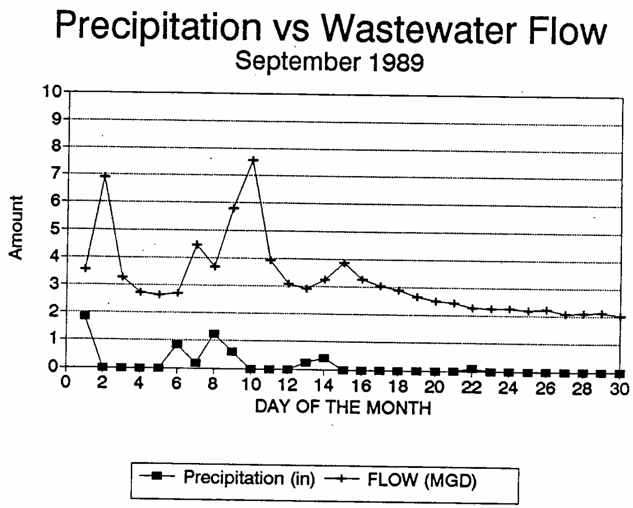


Figure 4-1. Discharge from Cedar Lake wastewater collection system vs. precipitation for May and September 1989.

4.3.1 Shoreline Erosion

Shoreline erosion is a significant problem in a number of areas along Cedar Lake's shoreline. The problem can be documented by photographs and personal accounts, but it is difficult to estimate the volume of shoreline eroded. Some residents report areas where 20 feet of shoreline have been lost.

The lake's shallow water depth, long wind fetch and heavy motor boat use all contribute to the large waves which erode the shoreline. The scarcity of rooted littoral vegetation and the sand and gravel texture of the scoured littoral sediments (Figure 2-36, page 78, Phase I Report) are further evidence of heavy wave action.

4.3.2 Septic System Failure

Effluent from improperly installed and/or maintained on-site septic systems contributed significant quantities of nutrients, bacteria and BOD to Cedar Lake in years past (see Phase I report). The construction of a wastewater collection system around the lake in the mid-1970s was intended to correct this problem. However, some landowners along the shoreline were reluctant to hook up to the collection system and continued use of marginal on-site systems may have been a problem until only recently.

As of September 1990, the remaining large block of shoreline septic systems agreed to be hooked up to the wastewater collection system. While new inputs to septic fields will now cease, leaching of old drain fields could be a residual source of septic system effluent to Cedar Lake.

4.3.3 Watershed Sources and AGNPS Modeling

Potential watershed nonpoint sources of pollution are numerous. Sources of such pollution include soil erosion and sedimentation on rural and urban land, eroding streambanks, and nutrient and organic materials from livestock wastes and agricultural land (Young et al. 1989). The identification of specific nonpoint sources is difficult because these sources are often distributed over the entire area of a lake's watershed. To assist us in identifying potential nonpoint sources in Cedar Lake's watershed and assessing their magnitude, we used the Agricultural Nonpoint Source Model (AGNPS).

The AGNPS model was developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS). The model was developed to analyze and provide estimates of runoff water quantity and quality from agricultural watersheds ranging in size from a few hectares to upwards of 20,000 ha (50,000 acres). AGNPS provides information on runoff volume and peak runoff, and estimates upland erosion, channel erosion, and sediment yield. In addition, AGNPS estimates the concentrations and masses of nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) contained in the runoff and the sediment.

Methods

AGNPS is event-based. As such, it works only for a single storm event of known volume and intensity. For Cedar Lake, we used a 3.55 inch rainstorm with an intensity of 73 foot-tons per acre-inch. This represents conditions that would be expected during a 24-hour storm with a frequency of once every five years. These values were obtained from the Soil Conservation Service (1966) from data for Indiana.

Because AGNPS can be run only for single storm events, annual yields of runoff, sediment and nutrients from the modeled watershed cannot be calculated. However, the model is still useful in comparing relative yields of these materials from specific watershed areas. In this way, AGNPS can be used to identify "hot spots" in the watershed that require management.

U.S. Geological Survey 7.5 minute topographical maps of the St. John and the Lowell quadrangles (scale 1:24,000) were used as a base map for Cedar Lake and its watershed (Figure 2-4). Clear acetate containing a grid of cells was laid over the base map. Each cell represented 40 acres. Only those cells with more than 50 percent of their area within the watershed boundaries were included (Figure 4-2). For Cedar Lake, a total of 142 cells were sufficient to cover the entire watershed.

For each of the cells in the Cedar Lake watershed, 22 separate parameters were determined. The following is a brief description of each parameter.

Cell Numbering. Each cell was numbered beginning in the northwest corner of the watershed and proceeding from west to east, southward. This numbering scheme, used in AGNPS for labeling cells, aided in quickly identifying specific cells in the program's output (see Figure 4-2).

Receiving Cell. The receiving cell is the number of the cell into which the most significant portion of the runoff from another cell drains. As arrows showing flow to receiving cells are connected, the patterns of surface water drainage within the watershed emerge. Figure 4-3 illustrates the surface water drainage pattern for the entire watershed. Cedar Lake's outlet at Cedar Creek is at cell #70.

SCS curve number. The SCS (Soil Conservation Service) or runoff curve number was used to estimate the direct runoff following storm rainfall. The amount of runoff is influenced not only by the amount of rainfall per storm, but also the amount of moisture in the soil prior to the storm (the more water in the soil, the less rain can penetrate into the soil, the more rain runs over the land). To keep the analyses constant, an average soil moisture condition was assumed. The values of the SCS curve number were obtained from a table developed in the AGNPS manual (Young et al., 1987). Since the SCS curve numbers depend on the land-use conditions within each cell, if more than one land-use occurred, a weighted average value was calculated.

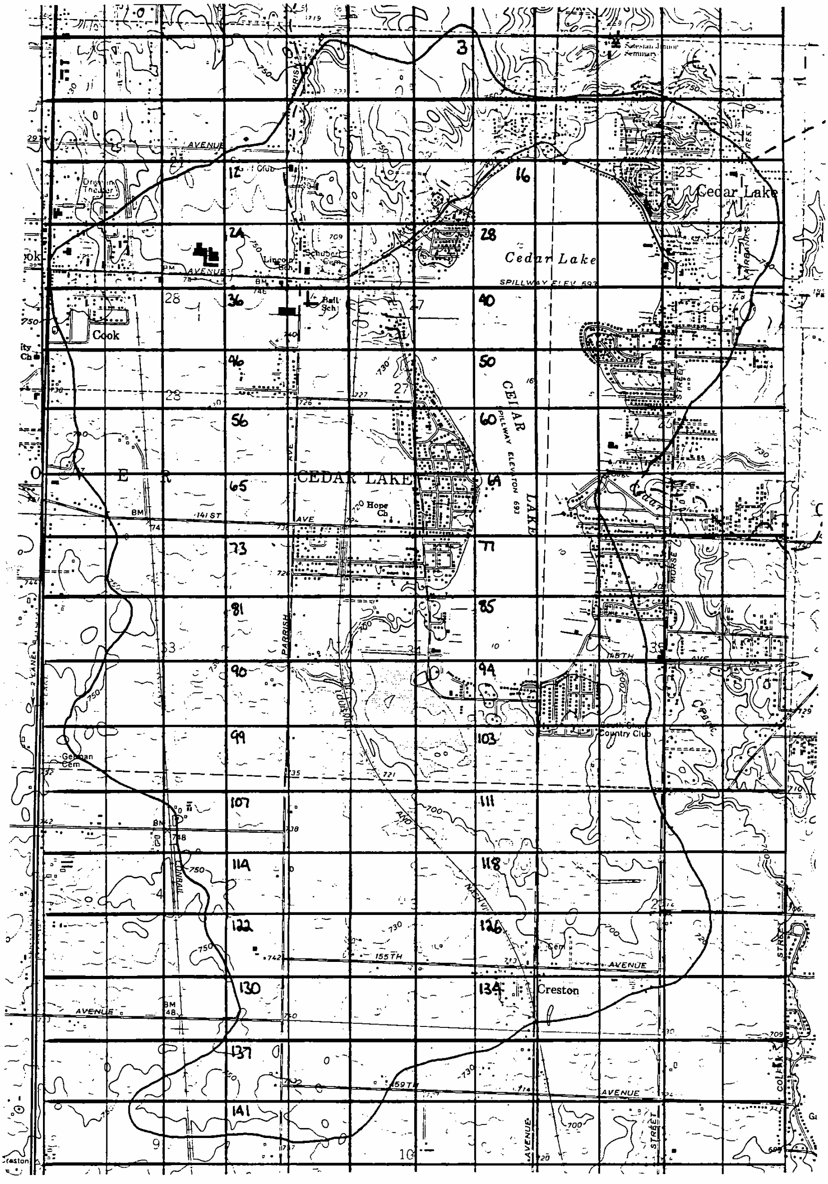


Figure 4-2. AGNPS cells in Cedar Lake's watershed.

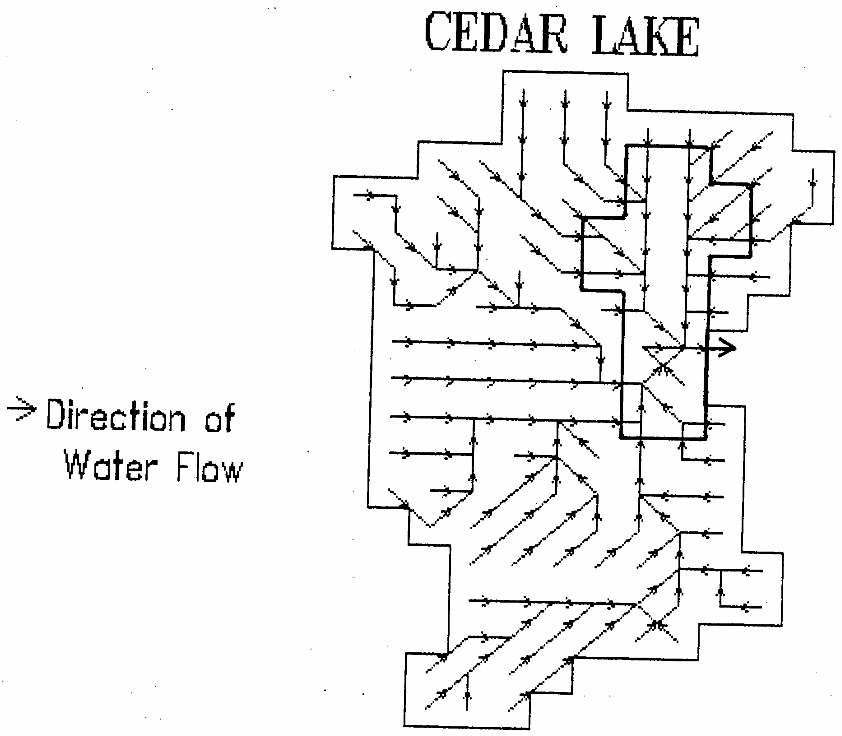


Figure 4-3. Surface water drainage in Cedar Lake's watershed.

Land Slope. Land slope influences the velocity of storm runoff and therefore the extent to which soil erodes. The land slope (in percent of rise) was determined from information provided by the Lake County Soil Conservation Agent (Roger Nanny, pers. com. 1989) based on the relationship between soil type and land slope.

Slope Shape Factor. The shape of the land surface within each cell was numbered one, two, or three for uniform, convex or concave slopes respectively. The slope shape factor was determined by examining the contour lines on the topographical maps.

Field Slope Length. The field slope length was determined from information provided by the Lake County Soil Conservation Agent and based on a weighted average of the soil types found in the individual cells.

Channel Slope. The channel slope was the average slope (in percent of rise) of the channel(s) within each cell. All channel slopes were assumed to be equal to the land slope. If there was no definable channel within the cell, a series of small channels with an average slope equal to half the land slope was used.

Channel Sideslope. The channel sideslope was the average sideslope (in percent) of the channel(s) within each cell. An average value of 10% was used except when a steeper slope was observed in the field, in which case either 40% or 90% was used.

Manning's Roughness Coefficient For Each Channel. The flow velocity of runoff depends on the roughness of the channel in which it flows. The rougher the channel bottom, the slower the water moves and therefore, the lower the erosive power. The Manning's roughness coefficient varies between zero and one (the higher the number, the smoother the surface), depending on the type of channel bottom. If no channel was definable within the cell, the roughness coefficient was chosen according to the main surface condition in the cell. If the cell was mainly water or marsh a value of 0.99 was used.

Soil Erodibility (K) Factor. The K-factor is also used in the Universal Soil Loss Equation (USLE). Its value varies between zero and one; the higher the number, the more erodible the soil. If the cell was mainly water or marsh, a value of zero was used.

Cover and Management (C-factor). Another USLE parameter, the C-factor is used to represent the cover and management of the land within the Cedar Lake watershed. The numbers were chosen to represent the worst-case condition (i.e. the fallow periods). Since the C-factor can be interpreted as the percent of soil lost per storm event, numbers were very low (e.g. between 0 and 0.1). Values of zero (for water or marsh), 0.01 (for urban or residential land), and 0.10 (for agricultural land) were used, as recommended in Young et al. (1987).

Support Practice (P) Factor. The P-factor is a parameter used in the Universal Soil Loss Equation to represent various conservation practices on agricultural lands. The worst-case condition was represented by a value of one for all agricultural lands. If the cell was mainly water or marsh, zero was used.

Surface Condition Constant. The surface condition constant was based on the land use at the time of the storm to make adjustments for the time overland flow takes to channelize. The lower the value, the greater the overland flow velocity.

Cell Aspect. The cell aspect is defined as the direction of flow leaving each cell (either out of the sides or the corners). Each of the eight possible flow directions were numbered, beginning with number 1 at the northern position and proceeding clockwise to number 8 at the northwestern position.

Soil Texture. The major soil texture found within each cell was characterized as either water, sand, silt, clay, or peat by using the Lake County Soil Survey (Persinger, 1972) and the textural triangle found in Young et al. (1987).

Fertilization Level. The fertilization level was a single digit designation for the level of fertilization on each agricultural field. In general, high levels of fertilization were assumed for all agricultural fields and golf courses (R. Nanny, pers. com. 1989). Zero fertilization was used for water and wetlands, and low fertilization for urban areas.

Fertilizer Availability Factor. The fertilizer availability factor is the percentage of fertilizer left in the top half inch of soil at the time of the storm. If none of the fertilizer had been incorporated into the soil, 100% (the worst case) would be available. For agricultural land, we used a value of 67% to characterize the tillage practices used in the Cedar Lake Area (chisel plow) (R. Nanny, pers. com. 1989). Where water or marsh conditions were found, a value of zero was used. If a cell was primarily urban, 100% was used.

Point Source Designator. The point source designator is a single digit representing the number of discrete pollution sources (feedlots, springs, waste treatment plants, etc.) found within each cell. The Cedar Lake watershed had no point sources designated.

Gully Source Level. While the AGNPS model provides estimates of soil erosion from channels and various land surfaces, it may underestimate soil losses from gullies. If desired, the modeler may make an on-site estimate of tons of soil lost from gullies and enter the amount under this parameter. We saw little evidence of gully erosion outside of established channels and for what little we did see, we were unable to visually estimate the tons of soil that could be lost during our modeled storm event.

Chemical Oxygen Demand (COD). Oxygen that is consumed or removed from the lake by nonbiological combination with chemicals in the water and mud is called the Chemical Oxygen Demand or COD. The values for the COD per cell depend directly on the land uses; from zero for water to 170 mg/l for row crops. The higher the COD value, the more oxygen will be removed.

Impoundment Factor. The impoundment factor indicates the presence of an impoundment terrace system within the cell. Since no impoundment terrace systems were found within the Cedar Lake watershed, this parameter was set to zero.

Channel Indicator. The channel indicator denotes the presence of a defined channel within the cell: zero indicates no defined channels; any other number signifies the number of channels in the cell.

Once the 22 parameters were compiled for each of the 142 cells within the Cedar Lake watershed, the same parameters were assembled for the Hog Pen Ditch watershed (20 40-acre cells located to the northeast of Cedar Lake). The Cedar Lake and Hog Pen Ditch data were separately entered into the AGNPS pollution model, the programs were run, and the outputs were interpreted.

AGNPS Results

The following figures show the results for the AGNPS model run with a 3.55 inch rainfall at an intensity of 73. Although the water in Cedar Lake is uniformly mixed, AGNPS follows the direction of water flow (Fig. 4-3) in assigning values. Thus, the output for runoff volume, sediment yield, etc. is not uniform within the lake boundaries.

The greatest amount of runoff for the simulated storm event (Fig. 4-4) is in the northern portion of the watershed, where land slopes are steepest or where pavement and residential development prevent infiltration. The peak flow of runoff (Fig. 4-5) is along established drainageways, for example, Sleepy Hollow Ditch, the wetland drainage ditch, and Cedar Creek. Sediment yields (Fig. 4-6) are highest along the drainage ways and from cultivated farmland, and low in the residential acres where little soil is exposed to erosion. Ten cells had soil erosion losses between 0.40-0.51 tons/acre, the highest category in our modeled event. All ten cells are in primarily agricultural land uses but cells 38, 48, 58, and 67 also have residential areas within them. Because these soil losses are calculated for a single storm event, it isn't possible to estimate the magnitude of annual soil losses or to compare the losses to "T" (tolerable soil loss) for Indiana.

Sediment phosphorus yields are shown in Figure 4-7. Sediment phosphorus is that phosphorus which is adsorbed to sediment particles. As such, sediment phosphorus yields are correlated with areas of soil erosion and phosphorus applications. In Cedar Lake's watershed, these areas include agricultural lands, lawns and golf courses. Figure 4-7 also shows that sediment phosphorus can be effectively trapped by Cedar Lake Marsh and Cedar Lake, and is not exported to downstream cells.

Soluble phosphorus and nitrogen are dissolved in water and is therefore associated with runoff volume and fertilizer applications. Agricultural lands and golf courses are large potential sources of these soluble nutrients. Figures 4-8 and 4-9 show that some of the soluble phosphorus and soluble nitrogen load can also be retained by Cedar Lake Marsh.

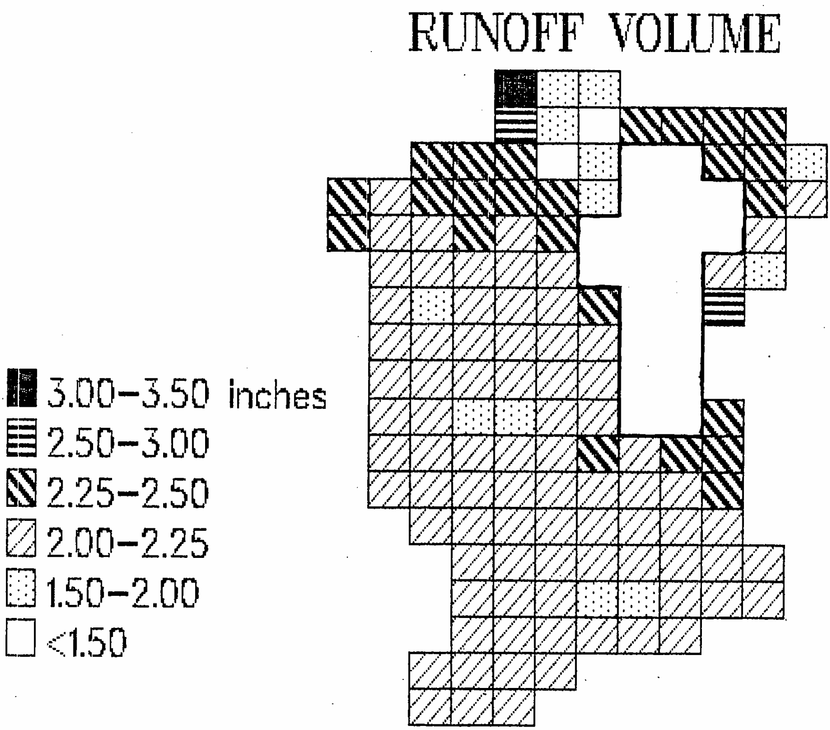


Figure 4-4. Runoff volume predicted by AGNPS for modeled storm event. Cedar Lake is outlined in white.

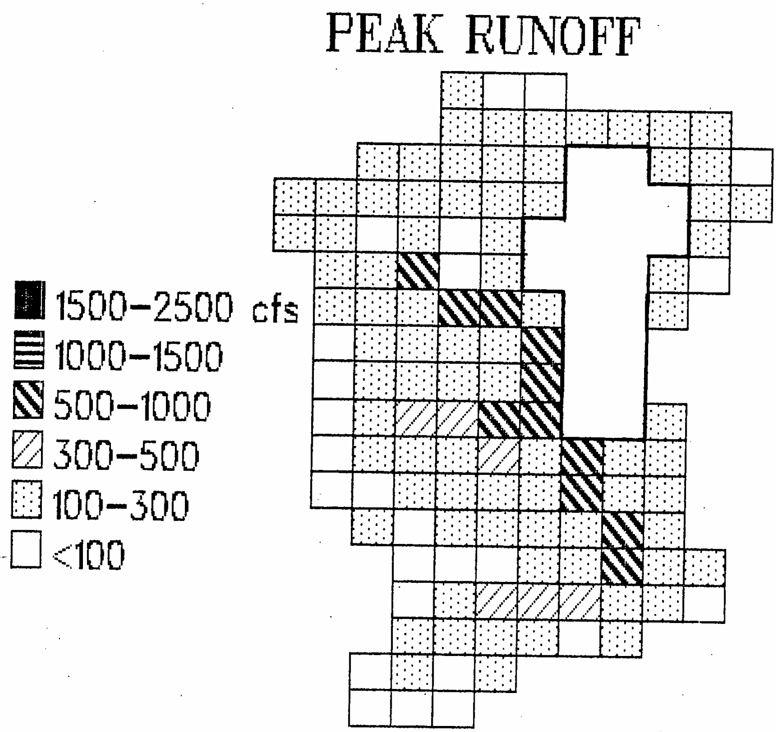


Figure 4-5. Peak runoff flow for modeled storm event.

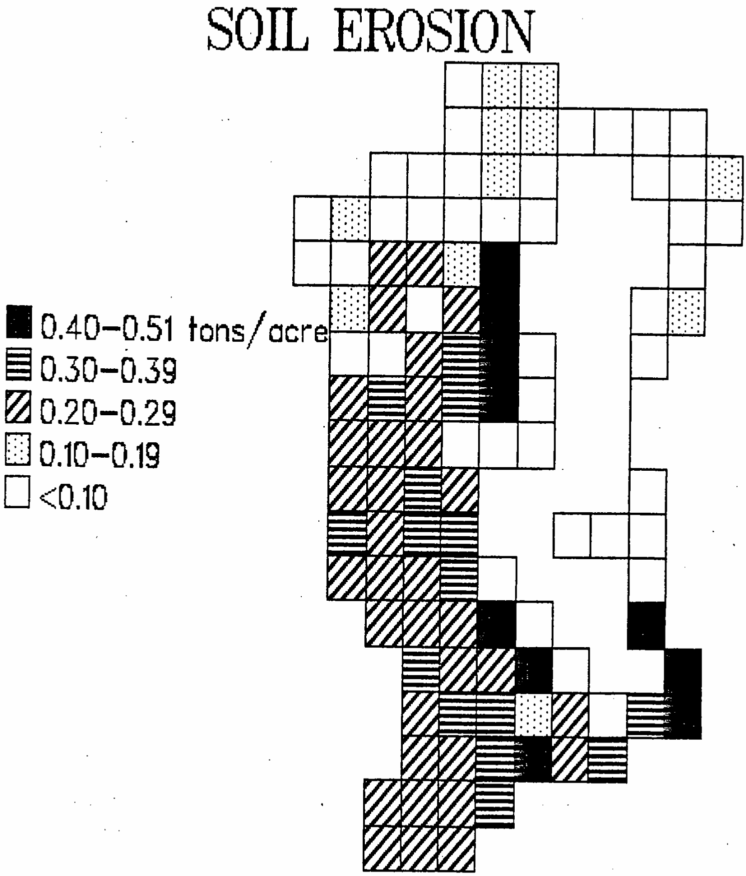


Figure 4-6. Cell soil losses during modeled storm event.

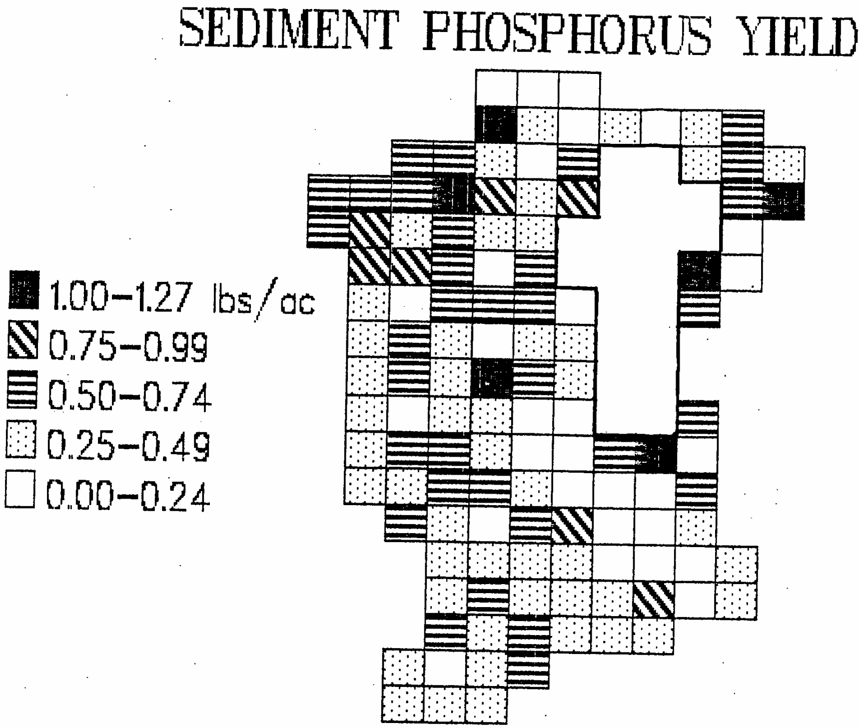


Figure 4-7. Sediment phosphorus yields for modeled storm event.

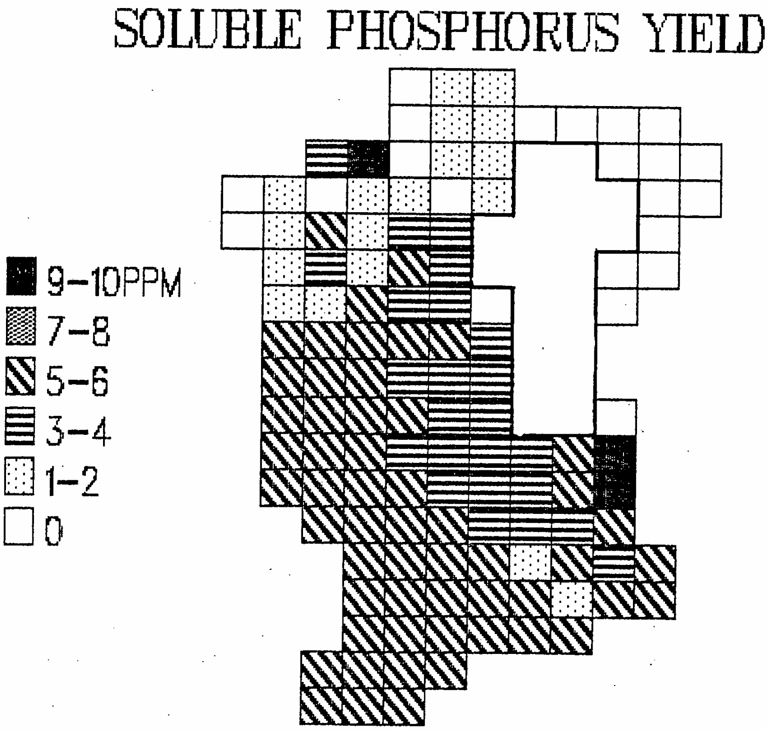


Figure 4-8. Soluble phosphorus yields for modeled storm event.

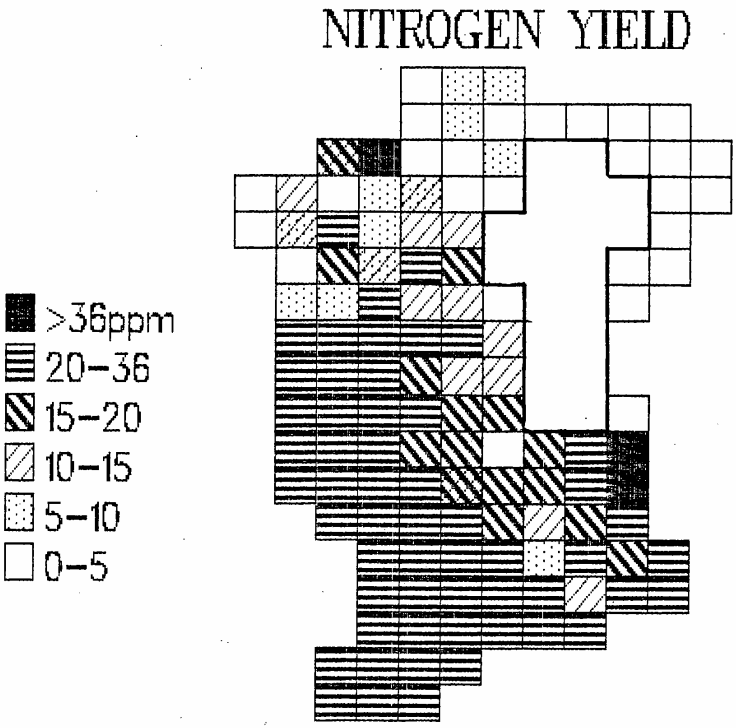


Figure 4-9. Nitrogen yields for modeled storm event.

Total yields for each cell draining directly into Cedar Lake are presented in Table 4-1. Of the major inlet streams, the South Shore Country Club Drain (Cell 95) carries the largest average runoff (251 m^3/ac), sediment yield (0.66 tons/ac), sediment phosphorus (1.14 lbs/ac) and soluble phosphorus (2.76 lbs./ac). The largest amount of phosphorus loading (sediment and soluble) enters Cedar Lake through Cell 94, the south wetland inlet that drains 1320 acres of mostly agricultural land to the south of the lake. As seen in Figures 4-7 and 4-8, this loading to the lake would be much larger if it did not pass through the wetland first where some of the phosphorus is retained.

We also ran AGNPS for the same 3.55 inch storm event for the Hogpen Ditch watershed (Fig. 2-4). Hogpen Ditch previously emptied into Cedar Lake but was rerouted to Cedar Creek below the lake in the early 1870's to lower the lake level and reclaim land for farming. The watershed of Hogpen Ditch is approximately 800 acres in size and includes agriculture (50%), woodland (25%), and urban (25%) land uses. The AGNPS analysis of Hogpen Ditch required twenty 40-acre cells to encompass its watershed. The outlet to Cedar Creek is from cell #18 (Fig. 4-10).

AGNPS plots of runoff, sediment yield, and phosphorus yield from the Hogpen Ditch watershed are shown in Figures 4-11 to 4-13. The maximum yields per cell for the Hogpen Ditch watershed are less than those for the Cedar Lake Watershed for runoff, sediment and phosphorus. While the area of the Hogpen Ditch watershed is 16.5 percent of the Cedar Lake watershed, sediment yield was just 6.1 percent, runoff was 7.9 percent, sediment phosphorus was 7.7 percent and soluble phosphorus was 12.7 percent of the Cedar Lake total (Table 4-1).

Sub-Watershed Comparison

Figures 4-14 to 4-15 compare sediment, sediment phosphorus, and soluble phosphorus yields from several of the major sub-watersheds within Cedar Lake's drainage basin for the modeled storm event. These figures allow further insight into which areas of the watershed may be sources of nonpoint source pollution. This can assist local officials in ranking watershed management priorities. Use Figure 4-2 to locate the graphed cells.

Highest predicted sediment losses are from the Cedar Point and Woodland Shores residential areas (cell 52) and from the South Shore Country Club (cell 95) (Figure 4-14). AGNPS may have overestimated these yields, although paved streets are an important sediment source for runoff water. All of the predicted sediment yields are well below the tolerable soil loss rate (T) for Indiana. This is most likely due to the gentle topography which characterizes most of Cedar Lake's watershed. It is interesting to note that the lowest predicted sediment yields are from Cedar Lake Marsh (cell 103). Agricultural lands draining into the wetland (cell 126) yield more sediment but the wetland can function as an effective sediment trap. The channelized wetland drain (cell 84) was not as effective a trap for sediments.

TABLE 4-1. AGNPS Results for Lake Inlet Cells

-CEDAR LAKE-

CELL NUMBER	DRAINAGE AREA (acres)	SEDIMENT YIELD (tons)	RUNOFF VOLUME (m3)	SEDIMENT PHOSPHORUS (lbs)	SOLUBLE PHOSPHORUS (lbs)
7	40	4.22	10073	10.4	74.0
8	40	4.01	10073	10.0	74.0
9	40	8.57	10073	18.4	66.8
15	120	43.61	18873	84.0	37.2
18	80	10.07	20148	24.0	148.0
19	40	11.33	10073	23.2	74.0
27	160	64.04	27138	121.6	105.6
31	40	9.98	10073	20.8	74.0
38	240	44.42	57729	98.4	465.6
43	120	47.49	26521	90.0	148.8
48	80	25.36	16611	50.4	152.0
52	80	48.96	16529	85.6	74.4
59	40	9.30	10073	19.6	74.0
62	40	12.57	12089	25.2	158.0
76	1200	170.91	261507	396.0	2304.0
84	1040	85.67	218087	218.4	2121.6
87	40	9.77	10073	20.4	74.0
94	1320	498.97	276803	963.6	2692.8
95	80	52.94	20148	91.2	293.6
TOTALS	4840	1162.19	1042694	2370.8	9212.4

-HOGPEN DITCH-

18	800	70.92	82235	184.0	1168.0
% of TOTAL	16.5	6.10	7.9	7.7	12.7

NOTE: Cedar Lake Cell 76 = Sleepy Hollow Ditch
" " Cell 84 = Wetland Drain
" " Cell 94 = South Wetland Inlet
" " Cell 95 = South Shore C.C. Drain

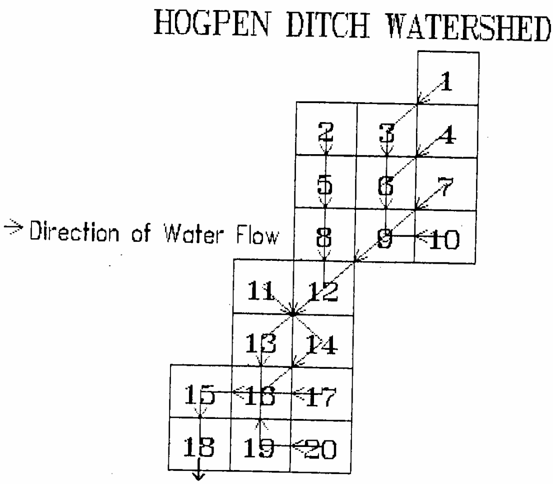


Figure 4-10. Hogpen Ditch AGNPS cells and surface runoff patterns.

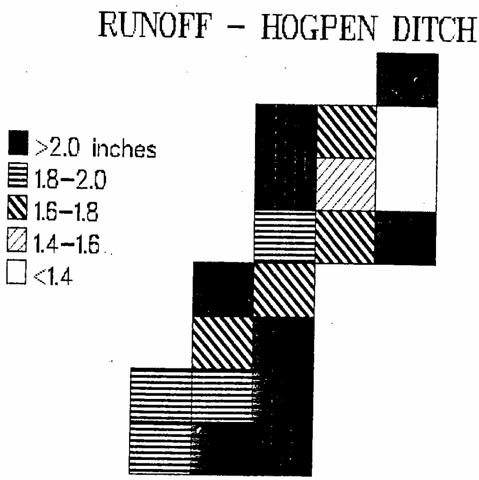


Figure 4-11. Hogpen Ditch runoff volume for modeled storm event.

Figure 4-12. Hogpen Ditch sediment yields for modeled storm event.

Figure 4-13. Hogpen Ditch soluble phosphorus yield.

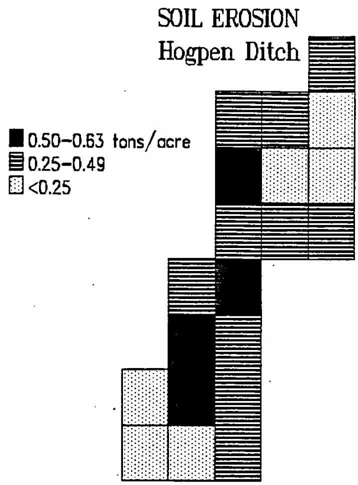


Figure 4-12. Hogpen Ditch sediment yields for modeled storm event.

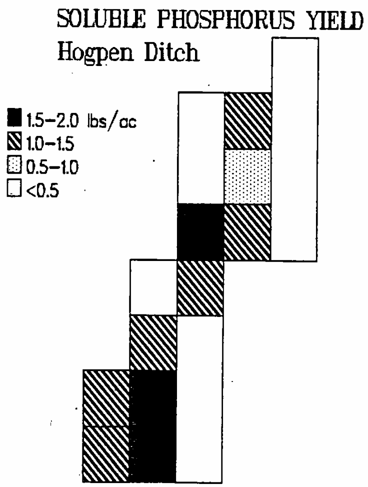


Figure 4-13. Hogpen Ditch soluble phosphorus yield.

Sediment phosphorus yields (Figure 4-15) mirror the sediment yields. Residential areas can be important phosphorus sources and this is reflected in the high phosphorus yields predicted for cell 52. Reckhow et al. (1980) report urban total phosphorus losses of 2 to 4 pounds per acre.

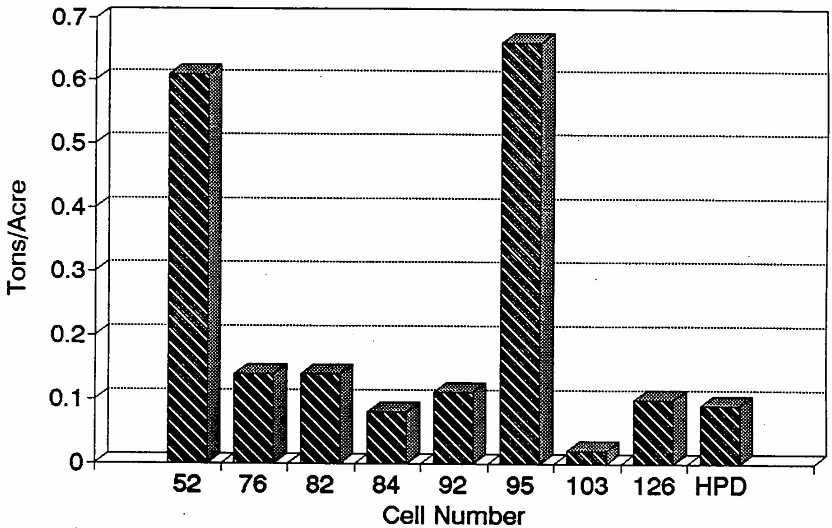
The highest predicted soluble phosphorus yields are from the South Shore Country Club (cell 95), agricultural lands to the south (cell 103), and the channelized wetland drain (cell 82) (Figure 4-16). The lowest soluble phosphorus yield was from cell 52, a largely residential area. This appears to be an underestimation. Hogpen Ditch had relatively low soluble phosphorus yields.

Use of AGNPS Results

How can we use the AGNPS results? AGNPS calculates rates of runoff, erosion, and nutrient export for 40-acre cells based on generalized conditions (data input) within each cell using standard equations governing these processes. The results likely represent worst case conditions. The actual yield could differ significantly and depends on specific use and management of the land. For example, existing fertilizer management practices on the golf course could reduce actual nutrient losses below those predicted by AGNPS. Likewise, AGNPS could underestimate actual soil or nutrient losses if landowners use poor land management practices.

AGNPS identifies areas of potential concern. It is up to local officials, working with the Division of Soil Conservation and the Soil Conservation Service, to field check cells which AGNPS identifies as potential sources of nonpoint source pollution. If the model's output is verified, then nonpoint source management practices can be recommended to address the problem (see Section 6.0).

Figure 4-14
Sediment Yields from Sub-Watersheds



LOCATION KEY

52 = east lakeshore
76 = Sleepy Hollow Ditch
82 = west ag. lands
84 = west wetland drain
92 = southwest ag. lands
95 = South Shore C. C.
103 = S. wetland discharge
126 = south ag. lands
HPD = Hogpen Ditch

Figure 4-15
Sediment P Yields from Sub-Watersheds

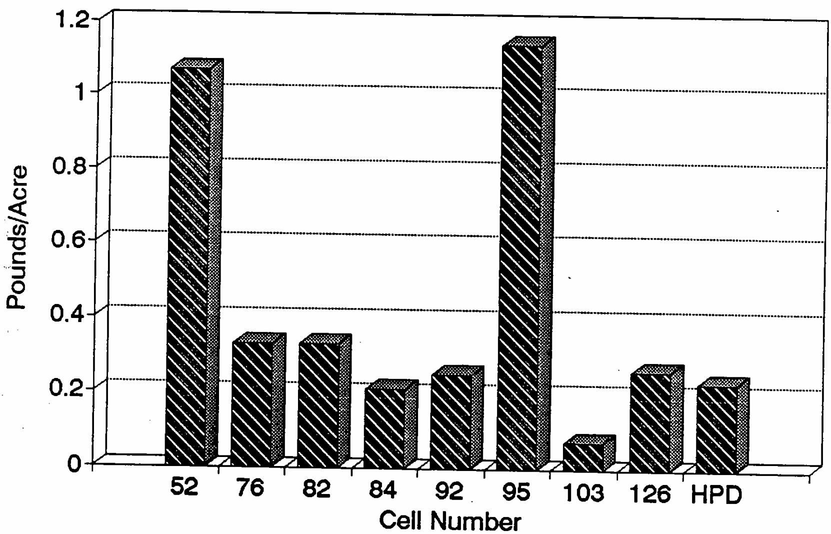


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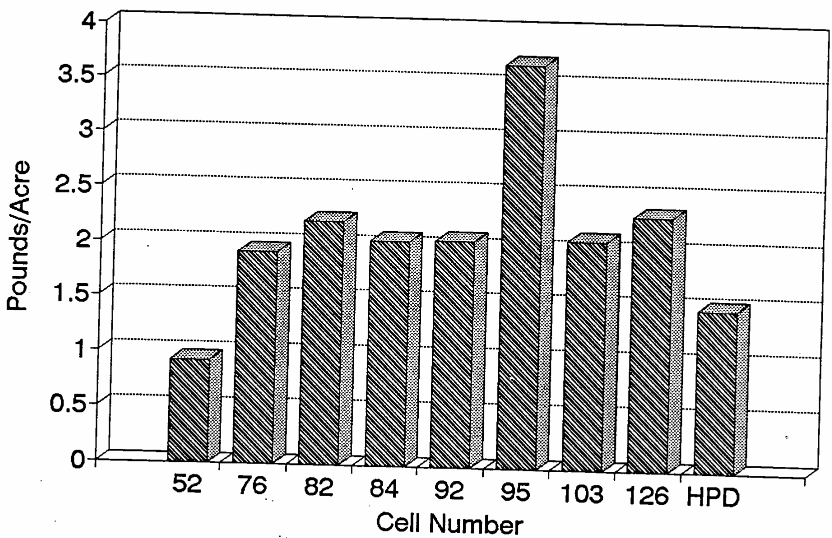
Figure 4-16

Soluble P Yields from Sub-Watersheds



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5.0 WETLANDS EVALUATION

To better understand the role of wetlands in affecting the quantity and quality of water in Cedar Lake, we conducted additional studies of wetlands contiguous to the lake. The largest and most significant of these is Cedar Lake Marsh.

5.1 DESCRIPTION

Cedar Lake Marsh, a 403 acre (163 hectare) wetland lying immediately to the south of Cedar Lake, has been identified by Goodwin and Neiring (1975) as the "largest continuous marsh in the state." Lindsey et al. (1969) suggest that the wetland is intrinsically suited for a wetland preserve.

Cedar Lake Marsh was a part of Cedar Lake until the lake level was lowered in the early 1870s. Since that time, the wetland has been isolated from the lake by a strip of filled land running along the south shore of the lake. Residences have encroached upon the wetland and additional filling has occurred at many locations. A small open dump extends into the south end of the wetland although it is reportedly now inactive. From around 1940 to 1960, 80 acres of the northwest section of Cedar Lake Marsh were artificially drained by cutting a channel through that section of the wetland to the lake. The area was cultivated and farmed during that period.

During the 1979-1982 study, we mapped the vegetation of Cedar Lake Marsh using aerial photographs obtained from the Agricultural Stabilization and Conservation Service (ASCS) and the Northwestern Indiana Regional Planning Commission. Major features of the largely herbaceous wetland are shown in Figure 5-1.

Approximately one-half of Cedar Lake's drainage basin drains into Cedar Lake Marsh. Drainage patterns through the wetland are shown in Figure 4-3. Flow across the wetland is restricted by an old railroad grade which is breached only in one section (see Fig. 5-1). This causes seasonal flooding of areas in the northwest portion of the wetland. Runoff from approximately 1000 acres of land to the west is directed into the old wetland drainage ditch and the remaining 1300 acres of land to the south and west drains through the main wetland and flows into Cedar Lake at AGNPS cell 94.

5.2 WETLAND NUTRIENT AND SEDIMENT TRAPPING FUNCTIONS

Wetlands receive, hold, and recycle water, sediments and nutrients from upland areas. Natural filtration, sedimentation, and other processes help clear the water of many pollutants. Some are physically or chemically immobilized and remain permanently in wetland soils unless disturbed. Wetland soils remove nutrients from water by (1) ion exchange, (2) precipitation reactions, and (3) complexation (Faulkner and Richardson, 1989). They also serve as attachment sites for microbial populations, which break down complex compounds into simpler substances through decomposition processes (Hammer and

Bastian, 1989). The sediment-litter compartment is the major pool of nitrogen and can contain up to 95 percent of the phosphorus in the wetland system.

Wetland plants, on the other hand, contain a relatively small amount of the total pool of phosphorus. Wetland plants remove nutrients through absorption and assimilation for biomass production through photosynthesis. This process returns oxygen to the water as an important by-product. Emergent plants use their roots to obtain sufficient nutrients from the interstitial water within the sediments. Floating species have roots with root hairs that can obtain nutrients from the water column. Submerged plants use nutrients from both the sediments and the water column (Guntenspergen et al., 1989).

Many nutrients are held in the wetland system and recycled through successive seasons of plant growth, death and decay. If surface water leaves the wetland, nutrients trapped in the wetland soils or vegetation during the growing season do not contribute to noxious algal blooms and excessive aquatic plant growth in downstream lakes. Surface water leaving the wetland during the fall and winter may contain substantial amounts of nutrients from decaying plant material, but this will not promote immediate plant growth in downstream waters because it occurs at a time of year when plants are dormant.

5.3 PHOSPHORUS DYNAMICS IN CEDAR LAKE MARSH

We used a simple batch test (Robert H. Kadlec, pers. comm.) to study phosphorus dynamics in Cedar Lake Marsh soils. Our goal was to test the rate at which the wetland soils could remove phosphorus from runoff water. Intact, duplicate soil samples were extracted from four locations (Figure 5-1) using seven centimeter-diameter acrylic plastic coring tubes. The overlying water was pumped out with a hand pump. Care was taken to not disturb the soil surface. The cores were then sealed and put on ice. In the lab, runoff water from Sleepy Hollow Ditch was spiked with phosphorus to a concentration of 245 ug/l to simulate nutrient-laden runoff. One thousand milliliters of this spiked water was gently added to each of the tubes and to an empty tube which served as a blank. The tubes were placed in a constant temperature room and allowed to react. Once every twenty-four hours, a sample was carefully withdrawn and the water was gently stirred. Samples were analyzed for soluble reactive phosphorus (SRP).

The rate of phosphorus uptake (or release) is determined by the concentration gradient between the overlying water and the interstitial water within the sediments. For example, if the concentration of phosphorus in the overlying water is higher than the concentration in the interstitial water, the sediments will take up phosphorus. Phosphorus in the overlying water can also be physically adsorbed to the sediments if adsorption sites are available.

Table 5-1 and Figures 5-2 and 5-3 show the results of this experiment. Sediments from Sites 1 and 3 both removed phosphorus from the water (Figure 5-2). Most uptake occurred during the first 24 hours, after which an equilibrium was reached between the water and the sediments (Figure 5-3). Soils from

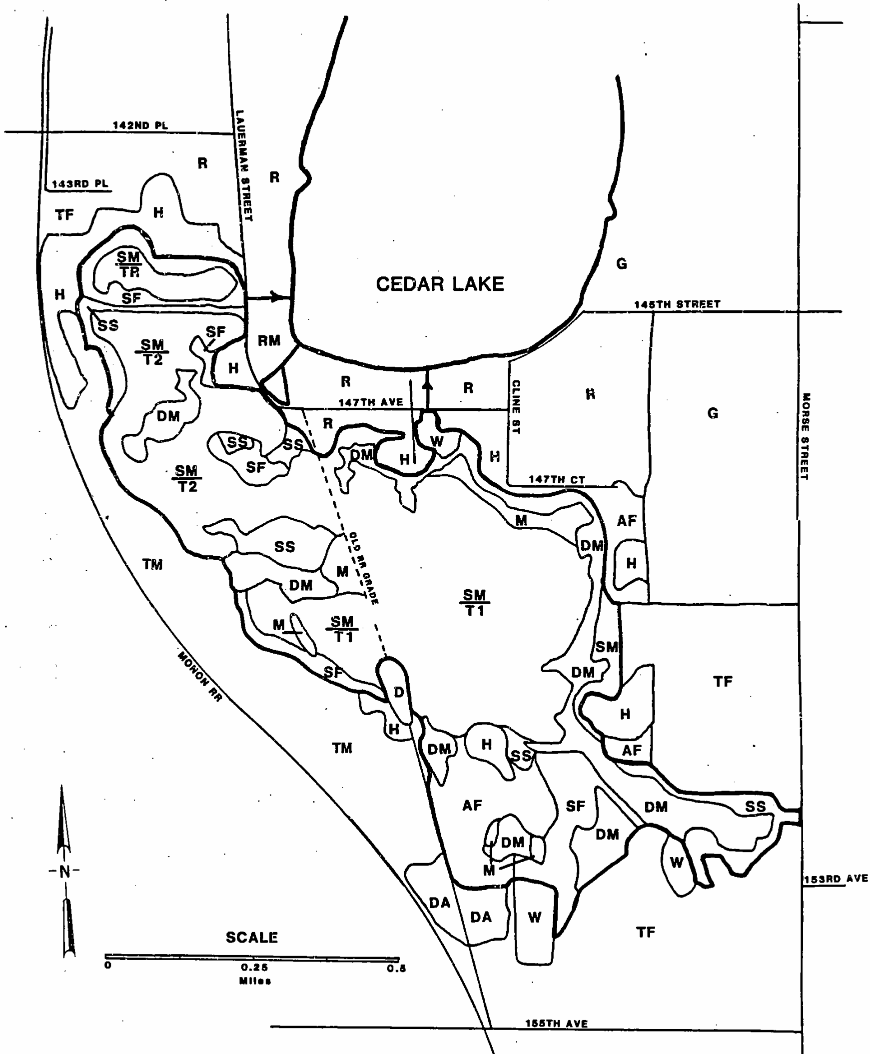

Figure 5-1. Generalized vegetation map of Cedar Lake Marsh.

LEGEND

AF — Abandoned field
D — Dump
DA — Automobile dump
G — Golf course
H — Hardwoods
M — Flooded meadow
R — Residential
RM — Marina
SF — Seasonally flooded
SM — Shallow marsh
SS — Shrub swamp
T — Cattail community
TF — Tilled field
TR — Cattail/swamp rose community
W — Open water
TM — Tree farm

1 — Dense vegetation
2 — Open water prevalent

Site 2 had a small net phosphorus release but those from Site 4 released a large amount of phosphorus. Site 4 is at the mouth of the wetland drainage ditch and these results suggest that that site has been overloaded with phosphorus. Site 2 is close to the old open dump and may have received inputs from that source.

Overall, these results suggest that soils within Cedar Lake Marsh can be used for nonpoint source phosphorus control, especially if runoff is directed out into the middle of the marsh. The area around Site 4 is likely a phosphorus source to Cedar Lake because of the heavy and concentrated phosphorus loading it receives.

TABLE 5-1. Cedar Lake Wetland Cores SRP Release Rates

SITE	RELEASE RATE (mg/m2/day)			TOTALS	
	24 HR	46 HR	72 HR	CHANGE IN MASS (ug)	MEAN RELEASE (mg/m2/day)
1	-18.7	0.46	3.55	-57	-4.94
2	6.76	11.44	12.84	119.4	10.35
3	-33.26	-2.52	-0.79	-140.7	-12.19
4	31.7	44.89	35.91	431.8	37.41

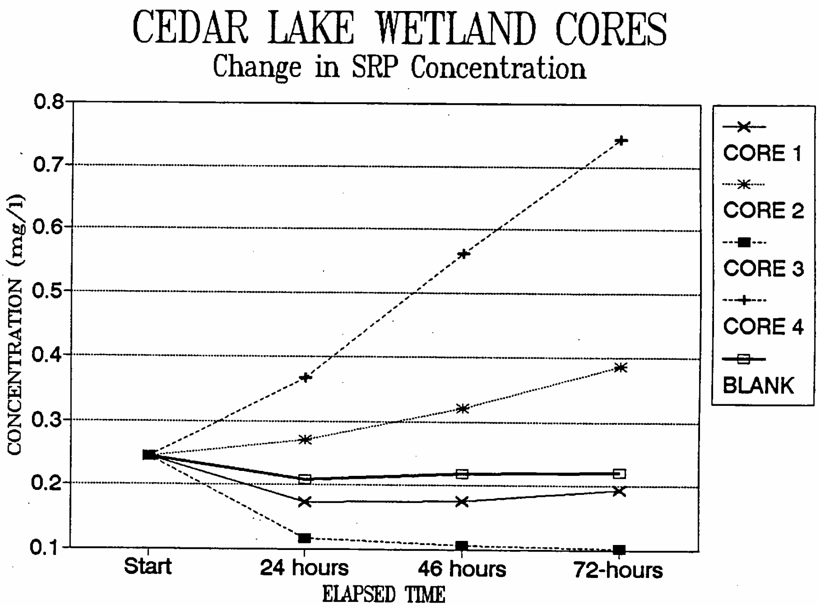

Figure 5-2. Change in overlying water phosphorus concentration.

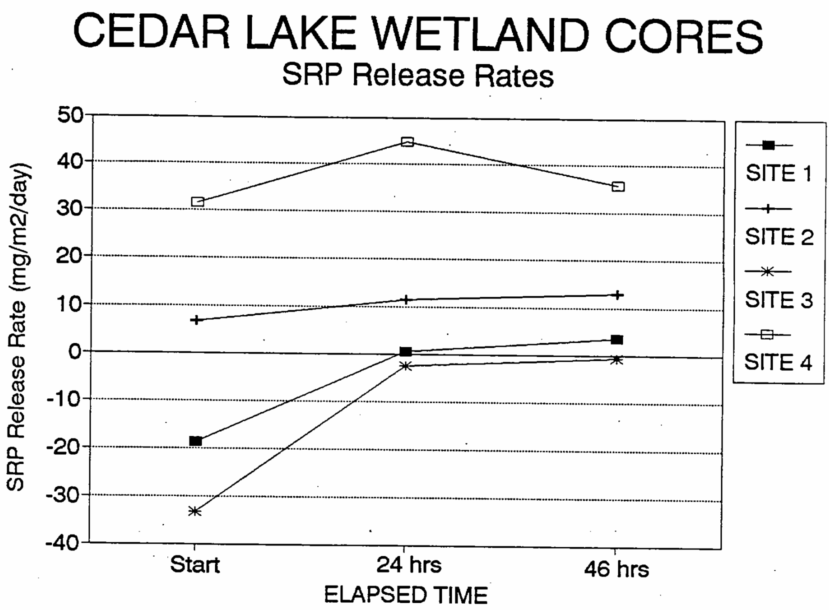

Figure 5-3. Mean phosphorus release rates.

6.0 SEDIMENT AND NUTRIENT CONTROL

The results of the AGNPS modeling suggest that human and land use activities in Cedar Lake's 4,837 hectare watershed are the primary sources of sediment and nutrient loadings to the lake. This is consistent with Willett (1980) who estimated that 70 percent of all sediment pollution nationally is caused by human activities. Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, Best Management Practices (BMPs) can be used to prevent or reduce nonpoint source pollution. While BMPs were developed originally for agricultural pollution control, they have now been adopted for urban nonpoint source control as well.

The degree to which BMPs should be used depends upon many factors including soils, topography and the individual farm or land management operation. It is not practical to select a specific set of BMPs without knowledge of these factors. Making these specific selections for each site in the Cedar Lake watershed is beyond the scope of this project.

Therefore, in the following section, we give an overview of BMPs and other practices for controlling agricultural and urban sources of nutrients and sediments. We refer the reader to a number of excellent publications for more detailed information on the subject. We have used these publications to prepare the material following. They include: Soil Conservation Service (1983); Garman et al. (1986); Moore and Thornton (1988); and UWEX (1989).

6.1 AGRICULTURAL BMPs

The following practices are designed to control the loss of both soils and nutrients from agricultural lands. Practices that prevent soil erosion are also important in controlling particulate forms of nutrients. Soluble (or dissolved) nutrients are controlled along with runoff.

6.1.1 Conservation Tillage

Conservation tillage is a farming practice that leaves at least 30 percent of the crop stalks or stems and roots intact in the field after harvest. Its purpose is to enhance water infiltration, reduce water runoff and soil erosion compared to conventional tillage where the topsoil is mixed and turned over by a plow. This practice can reduce sediment loss by 40-90 percent, particulate phosphorus loss by 25-70 percent and dissolved phosphorus loss by 25-42 percent.

6.1.2 Contour Stripcropping

In this practice, the farmer plows across the slope of the land. Strips of close growing crops or meadow grasses are planted between strips of row crops like corn or soybeans. Contour stripcropping on 2 - 7 percent slopes can reduce soil erosion by 75% compared to plowing up and down the slope. Particulate and dissolved nutrient losses can be reduced by up to 50 percent.

6.1.3 Crop Rotation

Crop rotation involves periodically changing the crops grown on a particular field. Rotations are most effective if row crops are alternated with pasture in two to four year rotations. Pasture rotations improve soil structure, increase organic matter content and increase soil porosity relative to continuous row cropping. Nutrient losses can be reduced by 50 percent or more when pasture rotation is used.

6.1.4 Grassed Waterways

Grassed waterways are natural or constructed waterways or outlets, shaped or graded, and established in suitable vegetation to provide for removal of excess surface water. These vegetated channels reduce gully erosion, increase water infiltration, and trap sediment and nutrients. Sediment losses can be reduced by 60-80 percent in the grassed waterway.

6.1.5 Buffer Strips

Buffer strips are strips of grass or other close-growing vegetation intended to remove sediment or other pollutants from sheet flow runoff. They are usually placed along streams or lake shores, around feedlots, and at the edges of fields to prevent pollutant transport from human-disturbed areas. Sediment reductions of 30-50 percent are possible for a properly designed buffer strip. When used to control runoff from feedlots, sediments can be reduced by up to 80 percent and nutrients reduced by 60-70 percent.

6.1.6 Animal Waste Management

This is a practice where animal wastes are temporarily held in waste storage structures until they can be safely utilized or disposed. Outside storage areas should be covered to prevent water accumulation and runoff. Once fields have thawed in the spring, the stored wastes can be applied and the nutrients contained within them can infiltrate into the soil. Animal wastes should <u>not</u> be applied to frozen fields in the winter. Runoff over the frozen soil can transport the wastes and their nutrients off site.

6.1.7 Fertilizer Management

Fertilizer management is a practice used to decrease the availability of nutrients to runoff while providing optimum amounts of plant nutrients for crop production. It is the most important practice in controlling water pollution by nutrients from agricultural lands. Soil tests are probably the most important guide to the proper use of fertilizers. These tests, combined with information about soil type, previous cropping, and the anticipated soil moisture level, should be used to estimate fertilizer requirements. Apply fertilizer as close to the time of plant demand as possible, especially nitrogen fertilizers. If practical, all fertilizer should be incorporated into the soil to reduce loss by volatilization and surface runoff.

6.2 URBAN BMPs

The urbanization of watersheds can have important impacts on both the quantity and quality of stormwater runoff. For example, paved surfaces prevent the infiltration of precipitation resulting in a greater volume and velocity of runoff. Auto and bus exhaust, construction activities, and residential fertilizers are all urban sources of pollutants that can adversely affect lakes and receiving streams. In a study of urban runoff in Bellevue, Washington, Pitt (1985) calculated annual mass yields of 205 kg/ha of total solids, 90 kg/ha of chemical oxygen demand, 1.8 kg/ha of total nitrogen and 0.4 kg/ha of total phosphorus. Residential lawns contributed 83 percent of the total solids and streets contributed 45 percent of the COD, 32 percent of the phosphorus and 31 percent of the total nitrogen. Driveways, parking lots and residential lawns were the next highest sources of COD, phosphorus and nitrogen in the runoff.

The Urban Planning Development Guide prepared by the Hoosier Heartland RC&D Council (1985) is an essential reference for all urban nonpoint source problems and management practices. Readers are encouraged to acquire a copy of this guide.

6.2.1 Stormwater Management

The traditional approach to stormwater management was to use curbs, gutters and underground pipes to remove stormwater as quickly as possible to minimize local flooding. However, while these measures may relieve flooding of upstream areas, they contribute to the flooding and erosion of downstream areas that receive the rerouted stormwater. Recommended objectives and approaches to stormwater management have now expanded to include the mitigation of downstream flooding by:

1. Reducing the amounts of impervious surfaces such as driveways and roads.

2. Temporary stormwater storage in streets and parking lots, in grassy areas, in percolation trenches, and in ponds located both on and off the site.

3. Using grassed swales (vegetated channels) instead of curb and gutter. This costs less ($1-2/foot vs. $40/ft) and can remove up to 90 percent of total solids and 70 percent of phosphorus.

4. Using catch basins at the entrance to gutters to trap sediments.

5. Using sedimentation basins to detain stormwater and trap sediments and nutrients. Well designed wet sedimentation basins can remove 70-90 percent of solids and 60-70 percent of nutrients from stormwater runoff (Pitt, 1989). Basins need at least six feet of permanent standing water to protect the trapped sediments from scouring, to minimize rooted plant growth and to increase winter survival of fish. Correct basin side slopes are important to improve safety and

to minimize rooted plant growth (Jones and O'Reilly, 1986). The size of wet sedimentation basins should be approximately 0.5 percent of the size of the watershed which drains into it.

6.2.2 Construction Sites

Urban construction activities account for ten percent (or 500 million tons) of all sediments that reach U.S. waters each year. This is equal to the combined contributions of forestry, mining, industrial and commercial activities (Willett, 1980). In urban areas, construction activities may account for 50 percent of the sediment load. Construction sites have an erosion rate of approximately 10 to 200 tons per acre per year, a rate that is about 2 to 100 times that of croplands (Pitt, 1989). This high erosion rate means that even a small construction project may have a significant detrimental effect on local water bodies. For example, for a quarter-acre homesite cleared of vegetation, up to five tons of soil (one-half a truck-load) erodes from the site every month (Wisconsin DNR, 1982).

The following no-cost and low-cost practices can be useful in preventing erosion from construction sites (Wisconsin DNR, 1982):

1. Plan your construction activities so that the soil is disturbed a minimal amount of time. For example, plan to install gas pipelines, sewer laterals, and other utilities at close time intervals.

2. Leave grass, trees, and shrubs in place wherever you can. The more vegetation, the less sediment-laden water leaves your site.

3. When you excavate the basement, pile the soil away from stormsewer drains - in the back or side yard area, for example. Once you backfill around the basement, remove any excess soil from the site.

4. Park cars and trucks on the street not on the site. You'll keep the soil less compacted and more water-absorbent, and you'll keep mud from being tracked onto the street.

5. Arrange to have the street cleaned regularly while you're building to remove sediment that preventative measures failed to keep off the street.

6. Soon after you start construction, install a gravel driveway and encourage cars and trucks to use only this route on your site. Later, you can install the permanent driveway over the gravel.

7. Build a berm to divert rainwater away from steep slopes or other highly erodible areas.

8. Install straw bales or filter fences along curbs to filter rainwater before it reaches the gutter and stormsewer drains.

9. Seed and mulch, or sod your site as soon as you complete outside construction. You'll control erosion, and - if you're building for

a prospective buyer - you'll increase the lot's salability by making it more attractive.

10. If you can't seed and mulch the entire lot, cover any critical areas with a temporary protective material, such as filter fabric or netting. Later, you can remove the cover long enough to install utility lines.

11. Use roof downspout extenders and sump pump drain tubes to funnel water away from exposed soils and directly to the curb and storm-sewer. After site is vegetated, downspout extenders and drain tubes should outlet to the vegetated area to maximize infiltration.

While these practices are useful on individual lots, they are no substitute for an area-wide erosion control or storm drainage control regulation. The Highway Extension and Research Project has published a model erosion control ordinance (HERPICC, 1989). This along with the Urban Development Planning Guide prepared by the Hoosier Heartland RC&D Council, Inc (1985) are indispensable references for communities developing their own erosion control regulations. Remember, the most complete ordinance is meaningless unless it is enforced. Funds and personnel must be made available for active enforcement.

6.2.3 Fertilizer Management

Lawn and garden fertilizers can be important sources of nutrients to lakes, especially when applied to lakeshore property. Application rates should be sized to what the lawn or garden needs. Excess fertilizer can wash away, possible into a nearby stream or lake. This wastes money and contributes to nutrient enrichment of surface waters. Because grass has a high need for nitrogen, and because phosphorus is the nutrient which most often causes algae blooms in lakes, use lawn fertilizer formulas low in phosphorus. For example, fertilizers should contain less that 1/2 percent phosphorus if in liquid form or 3 percent if in granular form. It is best to have the soil tested *before* applying fertilizer on a lawn or garden. Contact your county extension agent for instructions or a simple kit for taking a soil sample. Soil samples can be mailed to testing laboratories for analysis for a modest fee.

Follow these guidelines for wise fertilizer management on the lakeshore:

1. Use fertilizers containing less than 1/2 percent phosphorus if in liquid form or 3 percent if in granular form.

2. Use organic fertilizers whenever possible. They release their nutrients slowly as the plants need them.

3. Make and use your own compost on your garden. It serves as a valuable weed-controlling mulch and an organic fertilizer. By using grass clippings and leaves in compost, they won't wash into the lake either.

4. Make sure that your soil is rich in organic matter. Nutrients in fertilizers stick to organic matter until needed by plants.

5. Do not apply fertilizers to your lawn or garden between November 15 and April 15. The plants can't use fertilizers during this period and the ground may be frozen, allowing the fertilizer to run off into the lake.

6. Leave a 25 foot fertilizer-free buffer along the lakeshore.

6.3 SHORELINE AND STREAMBANK PROTECTION

Few things are a bigger eyesore and problem for lakeshore property owners than an ugly, eroding shoreline. There are a variety of lake shoreline and streambank protection practices designed to stabilize and protect these areas against scour and erosion from forces such as wave action, ice action, seepage, and runoff from upland areas. Shoreline stabilization methods fall into two broad areas: nonstructural (vegetation or beach sloping) and structural (flexible structures such as rip-rap and rigid structures like seawalls) (McComas, 1986).

6.3.1 Shoreline Revegetation

Vegetation effectively controls runoff erosion on slopes or banks leading down to the water's edge; however, vegetation is generally ineffective against direct wave action or seepage-caused bank slumping. The type of vegetation to establish depends on the steepness of the slope. If the slope angle is steeper than 1:1 (i.e., 1 foot horizontal for every 1 foot vertical), the soil is probably unstable and the possibility of establishing protective vegetative cover is slight (McComas, 1986). Steep slopes should be re-graded to a 2:1 slope or flatter (SCS, 1989). All materials excavated from sloped banks may be placed on the bank, leveled, and seeded to prevent erosion during high water or hauled to other areas for use. Do not place excavated material into the lake or stream, or form barriers which interfere with runoff entering natural channels.

On long, steep slopes leading down to the water's edge where regrading to a gentler slope is too impractical (such as along the northwest shore of Cedar Lake), consider slope modifications which will allow vegetation to become established (Figure 6-1). Slope terracing provides horizontal steps in which to plant vegetation. Contour wattles are bundles of live willow cuttings anchored into the bluff face with either construction or live willow cuttings (Michigan Sea Grant Program, 1988). The bundles trap surface runoff and soil particles and lets vegetation become established.

Once an appropriate slope is created, seed or plant the bare soil immediately. Use erosion control mats of nylon mesh or wood excelsior on top of the soil to assist in seed germination, seedling protection, and erosion control. Time your work to coincide with optimal planting times. Grasses can be planted in the spring or fall while woody plants should be planted when they are dormant. A protective grass cover can be established within one year. Slopes should be 3:1 or flatter to facilitate mowing. Herbaceous

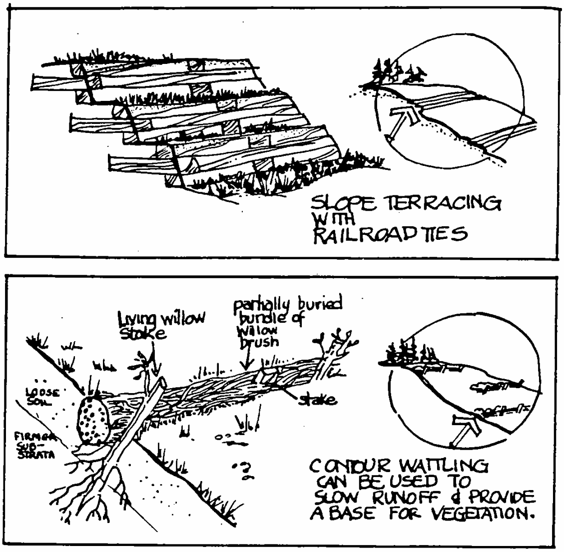

Figure 6-1. Modifications for long slopes. Source: Michigan Sea Grant Program (1988).

ground covers, shrubs and trees may take several years to become established. Ground covers are useful when mowing isn't desired. When using trees or shrubs to stabilize banks, plant grasses initially until the woody vegetation becomes established. A guideline for vegetative covers is presented in Table 6-1.

If regrading steep, eroded lakeshore slopes isn't possible, dormant woody plant cuttings can be used to vegetatively stabilize shorelines. The Illinois Water Survey has successfully stabilized eight-foot, 1:1 slope eroded streambanks with dormant willow posts (Illinois Resources, 1990; SCS, 1990). The willow post method uses 7-12-foot posts (one-half to three inches in diameter) that are placed in holes driven into the streambank (Figure 6-2). The willow posts are placed about four feet apart in offset rows. Within a few months, the posts regrow root systems and branches. Post length will vary with the depth to saturated soil and the bank elevation. About 40% of the post length must be buried in the bank, with the bottom of the post in the saturated zone. The Soil Conservation Service has approved the willow post technique for cost sharing funds. The SCS (1990) estimates that the average cost of regrading a 12 foot high bank to 1:1 slope is $77 per 100 foot length, and the cost per hole is $2.40 per 6 foot post and $2.90 per 9 foot post. Labor to cut and transport the posts can be calculated at 10 posts per person per hour.

TABLE 6-1. Vegetation for Lakeshore and Streambank Slopes. Adapted from: McComas (1986).

VEGETATION	>3:1 SLOPE	>1:1 SLOPE
Grasses	Kentucky bluegrass	red fescue switchgrass big bluestem little bluestem
Ground Covers	(same as >1:1 slope)	goutweed bearberry crown vetch memorial rose creeping juniper purple wintercreeper
Shrubs	(same as >1:1 slope)	red chokecherry gray dogwood sumac common juniper common witch hazel border privet snowberry tatarian honeysuckle
Trees	(same as >1:1 slope)	red maple silver maple paper birch white ash white pine black cherry

Willow Post Technique

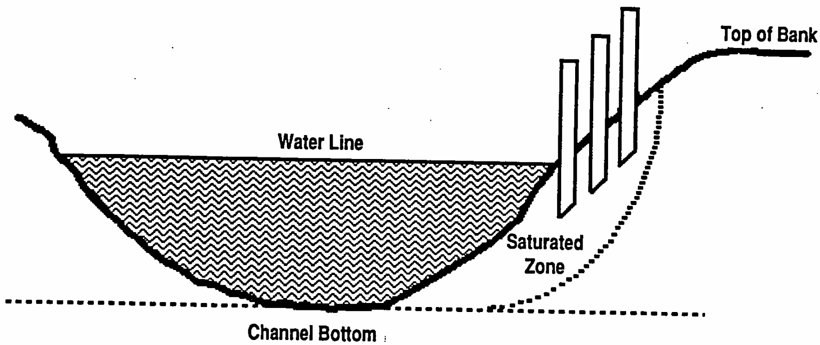

Figure 6-2. Willow post technique for steep streambanks and lakeshores.

6.3.2 Littoral Zone Revegetation

Diverse, moderately dense stands of aquatic plants are desirable in a lake's littoral zone. Emergent aquatic plant communities protect the shoreline from erosion by dampening the force of waves and stabilizing shoreline soils. Vegetation can also provide screening for the lakeshore homeowner and buffer noise from motor boats. Many species of aquatic plants, such as the white water lily and pickeralweed, are aesthetically pleasing because they have showy flowers or interesting shapes. Aquatic vegetation also provides fish habitat and spawning sites, waterfowl cover and food, and habitat for aquatic insects. For example, sedges (*Carex* spp.) become spawning beds for northern pike in spring, wild rice beds (*Zizania aquatica*) attract shorebirds in summer, and wild celery (*Vallisneria americana*) develops tubers that attract canvasbacks in fall and is one of the finest fish food and cover plants (Engel, 1988). Table 6-2 lists the positive attributes of some aquatic plant species.

A management goal should be to produce stable, diverse, moderately dense aquatic plant communities containing high percentages of species with desirable attributes (Nichols, 1986). This technique has been used successfully to enhance the benefits of aquatic vegetation in several Wisconsin lakes (Engel, 1984; Nichols, 1986; Engel, 1988). For example, 15,900 tubers of nine emergent and two submergent species were planted along the lakeshore and constructed islands in Elk Creek Lake, a 54-acre Wisconsin

TABLE 6-2. Aquatic Plant Attributes.

	NUISANCE RANK[1]	WATERFOWL FOOD VALUE[2]	POSITIVE AESTHETIC VALUE	OTHER
Emergent species				
Acorus calamus		S	X	human food[3]
Clyceria borealis		F		
Leersia oryzoides		F–G		
Pontederia cordata		S–F	X	
Sagittaria spp.		F	X	human food[3]
Scirpus cyperinus				shoreline protection
Scirpus validus		S–F		shoreline protection
Sparganium chlorocarpum		F	X	
Typha latifolia				food for aquatic fur bearers and humans[3] shoreline protection
Zizania aquatica		E	X	human food[3]
Floating-leaved species				
Brasenia schreberi	L	F–E	X	
Lemna minor		F–E		
Nelumbo lutea	L		X	
Nuphar spp.	L	F	X	
Nymphaea odorata	L	S	X	
Nymphaea tuberosa	L	S	X	
Polygonum coccineum		G–E		
Polygonum natans		G–E		
Wolfia spp.		F		
Submerged species				
Ceratophyllum demersum	R	S–F		good macroinvertebrate habitat[4]
Chara vulgaris	L	G–E		
Eleocharis acicularis		F–G		suppresses nuisance macrophytes
Elodea canadensis	R	S		
Heteranthera spp.				good macroinvertebrate habitat[4]
Myriophyllum spp.	R	S–F		good macroinvertebrate habitat[5]
Najas flexilis	L	E		
Najas quadalupensis	L	E		
Najas minor	L			
Potamogeton amplifolius		F		
P. crispus	R			good macroinvertebrate habitat[5]
P. foliosus		F–G		
P. gramineus		F–G		
P. natans		F–G		
P. pectinatus	L	E		
P. pusillus		F–G		
P. richardsonii		G		
P. strictifolius		F		
P. zosteriformes		F		
Ruppia sp.		E		
Utricularia vulgaris	L			
Vallisneria americana	L	E		
Zanichellia sp.	L	F–G		

[1] After Trudeau, 1982. R = regional problem, L = local problem
[2] After Carlson and Moyle, 1968. S = slight, F = fair, G = good, E = excellent
[3] Fernald et al. 1958
[4] Krull, 1970
[5] Krecker, 1939

Source: Nichols (1986).

impoundment, to stabilize slopes, improve water clarity, and attract waterfowl (Figure 6-3). Species with rapid growth rates, high productivity, and long growing seasons may interfere with water uses and should be avoided.

Plantings can increase the population of an aquatic plant species or the area of cover. Planting is labor intensive and may be expensive. Plant propagules must be collected or purchased from a commercial source. They then have to be weighted or placed directly in bottom sediment (Nichols, 1986). For example, tubers of wild celery and sago pondweed should be weighted with a 16 penny nail attached by a rubber band or sunk in mesh bags containing stones (Engel, 1988). Tubers and roots should be planted in the early spring. For some species that produce seed, the seed can be broadcast in the fall. An alternative method is to pack the seeds in mud balls before sowing.

Table 6-3 lists some rooted plants to grow in midwestern lakes needing habitat. Bulrushes (*Scirpus spp.*) are among the best emersed plants as far as withstanding the physical action of waves and currents. By buffering wind and wave action, this species allows other aquatic plants to gain a foothold and grow. Reed canary grass (*Phalaris arundinacea*) has deeply and intertwined root systems that binds shoreline soil well and they provide excellent cover for aquatic insects, fish fry, and waterfowl. The extensive root system of Sago pond weed (*Potamogeton pectinatus*) makes it carp-resistant and it is proclaimed as the best all-around duck food in North America (Wildlife Nurseries, 1990).

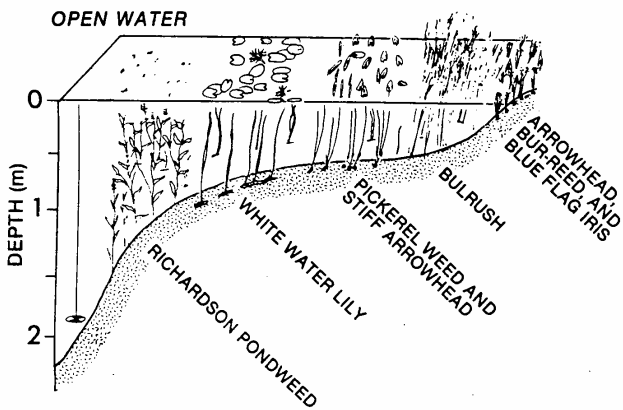

Figure 6-3. Revegetation plan for the shore of Elk Creek Lake, Wisconsin. Source: Engel (1988).

TABLE 6-3. Some Rooted Plants to Grow in Midwestern Lakes Needing Habitat.

Common name	Scientific name
Emergent species: plant rootstock in ankle-deep water.	
Common arrowhead	*Sagittaria latifolia*
Pickerelweed	*Pontederia cordata*
Slender spikerush	*Eleocharis acicularis*
Sweetflag	*Acornia calamus*
Reed canary grass	*Phalaris arundinacea*
Emergent species: plant rootstock or seed no greater than waist deep.	
Hardstem bulrush	*Scirpus acutus*
Common cattail	*Typha latifolia*
Sedge	*Carex spp.*
*Wild rice	*Zizania aquatica*
Floating-leaved species: plant rhizome no deeper than about 0.9 m (3 ft.).	
American lotus	*Nelumbo lutea*
White water lily	*Nuphar advena*
Yellow water lily	*Nymphaea tuberosa*
Submergent species: plant seed, cutting with leaf node, or whole plant no deeper than 10% of surface light.	
Broad-leaved pondweeds	*Potamogeton amplifolius, illinoensis, natans, richardsonii*
Narrow-leaved pondweeds	*Potamogeton berchtoldii, foliosus, pectinatus*
**Wild celery	*Vallisneria americana*

*Plant seeds only.
**Plant tubers or whole plant only.

Source: Engel (pers comm); Wildlife Nurseries (1990)

Two sources of aquatic plants and seeds in the midwest are:

Wildlife Nurseries
P.O. Box 2724
Oshkosh, Wisconsin 54903

Country Wetland Nursery, Ltd.
Box 126
Muskego, Wisconsin 53150

Prices vary depending on the species and whether tubers or seed are planted. For example, the following are current costs for 1,000 tubers, which will plant one acre at the recommended planting density: Sago pondweed ($130), wild celery ($140), and hardstem bulrush ($160). Enough reed canary grass seed to plant one acre costs $46.80 (at 12 lbs. per acre). Experience in Florida suggests that aquascaping projects will cost approximately $2,000 to $10,000 per acre (Miller, 1988). However, these costs can be reduced greatly by using volunteers to plant the tubers and seed.

6.3.3 Beach Sloping

Beach sloping takes advantage of the ability of semifluid sands to dissipate the energy of the breaking and receding waves (McComas, 1986). A typical cross section is shown in Figure 6-4. The final slope of the beach line is based on the size of the material used. Design considerations include:

1. Minimum thickness of the sand blanket is one foot.

2. Extend the blanket to a water depth two times the design wave height.

3. Extend the beach blanket the distance equal to the computed runup plus one foot.

4. The size of the material used and the final slope should be determined by a professional engineer.

One problem with beach sloping is that a strong along-shore current may erode the blanket material. Periodic replenishment will be necessary in this case.

6.3.4 Structural Methods

Riprap is a flexible structure constructed of stone and gravel which is designed to protect steeper (slope > 1:1) shorelines from wave action, ice action and slumping due to seepage. The riprap is flexible in that it will give slightly under certain conditions. This improves its ability to dissipate wave energy. Riprapping involves more than simply dumping rocks on the shoreline. Filter fabric or graded stone must be used on the soil base to prevent soil from moving through the stone and undercutting it. The toe

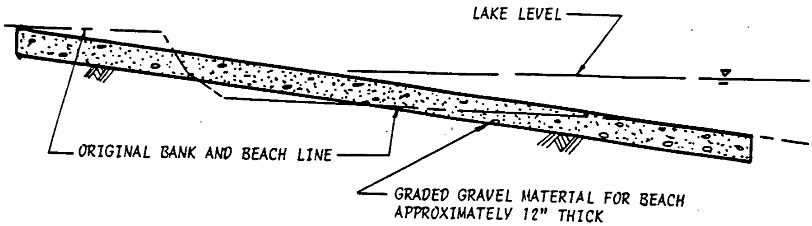

Figure 6-4. Cross section of beach sloping. Source: McComas (1986).

(bottom) of the riprap must be protected by burying it at least three feet below the sediment surface (Figure 6-5). The size of the largest stones used depends on the design wave height. See SCS Standards and Specifications 580 entitled, "Streambank and Shoreline Protection" (SCS, 1989) or your county SCS agent for more information.

Seawalls, bulkheads, and retaining walls are rigid structures used where steep banks prohibit the sloping forms of protection. Seawalls primarily prevent land masses from sliding from the shore into the water and secondarily prevent wave action from damaging the shoreline. Seawalls do not dissipate wave energy but rather, redirect the wave energy away from the shore. This often erodes the shoreline at the base of the wall and may affect the slope of the lake bottom some distance from shore. The cumulative effect of too many seawalls around a lake can be devastating to aquatic species.

The placement of riprap and seawalls is best left to the professional. *The use of both of these methods requires a permit from the Indiana Department of Natural Resources and may require a 404 Permit from the U.S. Army Corps of Engineers. These agencies must be contacted before any material is placed or deposited in a stream channel or on a lake bed.*

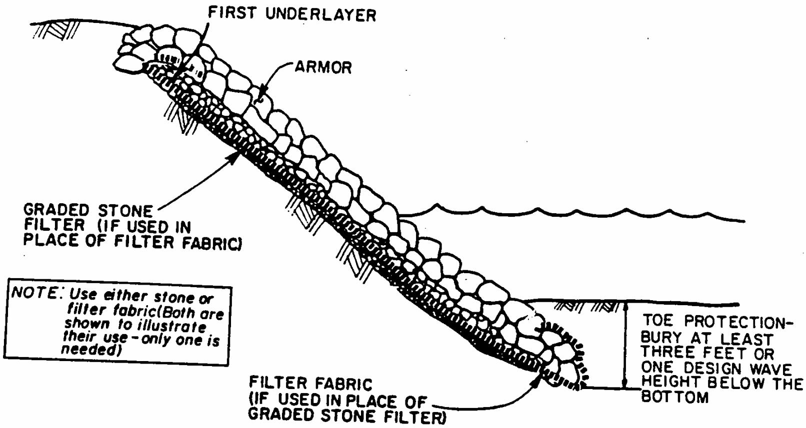

Figure 6-5. Cross section of a riprapped shore.
Source: McComas (1986).

6.3.5 Streambank Fencing

Cattle, hogs and other farm animals can destroy streambank structure and vegetative cover when they walk down or along streambanks to get water. This leads to serious erosion and sediment transport to downstream areas. Farm animals should not have unrestricted access to streams. Streambank fencing can be used to protect banks from farm animals. Stabilized crossings or access points should be constructed to allow farm animals access to the water if there are no other watering alternatives.

6.4 WETLANDS TREATMENT

6.4.1 Purpose

Wetlands are emerging as a low-cost, efficient treatment system for a wide variety of wastewaters, including: municipal wastewater, acid mine drainage, urban runoff and more recently, non-point source pollution (Watson et al., 1989). For example, the Indiana Department of Natural Resources T by 2000 Lake Enhancement Program has supported the use of constructed and reconstructed wetlands to protect lakes from sediment and nutrient inputs from their watersheds. Under this program, wetland treatment systems have been constructed at Lake Maxinkuckee and Koontz Lake in Marshall County and will be constructed at Prides Creek Reservoir in Pike County. Treatment efficiencies vary with design, vegetation used, soil conditions, and loading rates, but removal rates of 95 percent for sediment, 90 percent for total phosphorus, and 75 percent for total nitrogen are reported (Livingston, 1989).

6.4.2 Design Considerations

There are several important design considerations to consider for enhancing the sediment and nutrient removal efficiencies of constructed or enhanced wetlands. These include:

1. Sizing the wetland to the drainage area.
2. Reducing water velocities through the system.
3. Maintain optimal water levels.
4. Pretreatment to remove sediments.

Wetland surface area must be sized to meet the expected volume of water it receives. Design features should maximize runoff residence time which, in turn, enhances contact with wetland sediments, vegetation and microorganisms. Maryland's urban stormwater regulations suggest a designed detention time of 24 hours for the one-year storm event (Livingston, 1989). This will enhance pollutant removal and provide storage volume recovery between storms. If extended detention is not possible, then the wetland surface area should be a minimum of 3 percent of the contributing drainage area. Extended detention can be provided by incorporating a sedimentation basin into the wetland design.

High water velocities through wetlands can reduce soil and plant removal efficiencies and may even wash out rooted vegetation. Mechanical stress due to high water velocities can cause changes in vegetation leaf form, reduction in plant growth and may shift biomass from the leaves to the roots (Guntenspergen et al., 1989).

The wetland hydroperiod must be consistent with the needs of the vegetation used. Hydroperiod is the depth and duration of inundation measured over an annual wet or dry cycle. The proper hydroperiod determines the form, nature, and function of the wetland (Livingston, 1989). Water depth and inundation period can change the vigor and species composition of the wetland plant community. This can have detrimental impacts on the wetland or its nonpoint pollutant removal.

Finally, many wetland treatment systems incorporate presedimentation basins to remove some of the sediment load before it reaches the wetland. Sediment accumulation within the wetland can change plant species composition or even bury rooted vegetation. Pretreatment can not only enhance the functioning of the wetland but also extend its usable lifetime.

6.5 IN-LAKE TREATMENT

There are numerous in-lake methods available to combat the effects of excessive sediments and nutrients in lakes. Some of these include:

1. Dredging
2. Nutrient inactivation/precipitation
3. Dilution/flushing
4. Biotic harvesting
5. Selective discharge

6. Sediment exposure and desiccation
7. Lake bottom sealing
8. Biological controls

Each of these methods has been discussed thoroughly in the original Phase I Report (Echelberger et al., 1984) and will not be duplicated here. Refer to the original report for more information.

7.0 RECOMMENDATIONS

7.1 GOALS

Cedar Lake's water quality problems developed over a period of many decades. A primary cause of these problems, poorly-functioning lakeshore septic systems, has been eliminated by the wastewater collection system which was connected to most residences by 1980 and to the remaining 40 or so dwellings this past year. The lake has responded to these reductions in nutrient loading by modest improvements in water quality. Cedar Lake has always been shallow (as many ice-block lakes are) and turbid (due to the shallowness and long wind fetch). It is not feasible to expect to restore the lake to "crystal clear" conditions. Instead, the goal of this lake enhancement program has been to identify methods to "enhance" the current lake quality conditions.

The recommendations for enhancing Cedar Lake center on:

1. Reducing the generation of nonpoint sources of pollutants (sediments and nutrients) from agricultural and urban sources.

2. Reducing the delivery of nonpoint sources of pollutants to the lake.

3. Decreasing the concentration of nutrients already in the lake.

4. Controlling shoreline erosion.

5. Reducing the resuspension of sediments and nutrients within the lake.

7.2 AGRICULTURAL BEST MANAGEMENT PRACTICES

The AGNPS modeling identified several areas within Cedar Lake's watershed that have a high potential for generating sediment and nutrient nonpoint source pollution. The implementation of agricultural BMPs should be encouraged in cases where field checks confirm the presence of potential NPS pollution. These BMPs are reviewed in Section 6.1. The local Soil Conservation Service (SCS) and Soil and Water Conservation District (SWCD) representatives are valuable sources of information and assistance. Assistance to implement site-specific BMPs should be requested from these agencies.

7.3 URBAN BEST MANAGEMENT PRACTICES

Urban concerns identified during this study include: soil erosion, stormwater discharge, and fertilizer usage. The following actions address these concerns.

7.3.1 Erosion Control

Cedar Lake should adopt a comprehensive urban erosion control ordinance to control erosion from construction activities. A procedure used by other Indiana communities is to appoint an Erosion Control Task Force to investigate the problem, identify options, and make recommendations. The task force should be composed of 6 to 8 individuals representing a broad range of experience in this area; for example, an engineer, a planner, a builder, a geologist, etc. Use the manuals entitled, "A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities" (HERPICC, 1989) and "Urban Development Planning Guide" (HHRCDC, 1985) as resources. The county extension agent and the local SCS representative will also be important resources.

7.3.2 Stormwater Management

It is acceptable to discharge stormwater into Cedar Lake as long as sediments and nutrients contained in the stormwater are minimized. In this way, stormwater can aid in diluting the lake water and can increase the flushing rate of Cedar Lake. However, Cedar Lake should adopt a stormwater management plan to guide future actions. The same procedures used for developing an erosion control ordinance (Section 7.3.1) can be used.

Specifically, the stormwater drains from the intersection of Morse Street and 133rd Avenue must incorporate pretreatment. Before the stormwater is discharged into the lake, it should pass through a sedimentation basin or constructed wetland to trap sediments and nutrients. If the discharge isn't too severe, the two culverts could be replaced by a grassed waterway which will also filter out sediments and nutrients. The specific treatment can be determined during the T by 2000 Design Study should the community apply for one.

It is reported that Sleepy Hollow Ditch, which drains commercial and residential areas along the west side of the lake, floods Lauerman Street during heavy storm events. The road was apparently flooded twice during 1990. This ditch could be an important urban nonpoint source because it drains directly into Cedar Lake without treatment. Consideration should be given to rerouting this inlet to Cedar Lake marsh where suspended sediments and sediment-bound nutrients could be removed before the water drains into the lake (see Figure 7-1).

7.3.3 Fertilizer Management

The use of lawn fertilizers along lakeshore property should be carefully controlled. As discussed previously (Section 6.2.3), this can be an important source of nutrient loading to lakes. Public education through prepared brochures, newspaper articles, etc. should be sufficient. Enforcement may be necessary for persistent violators.

7.3.4 Wastewater Collection System Management

Overflow from the wastewater collection system may be an important source of pollution to Cedar Lake. A comprehensive evaluation of the system

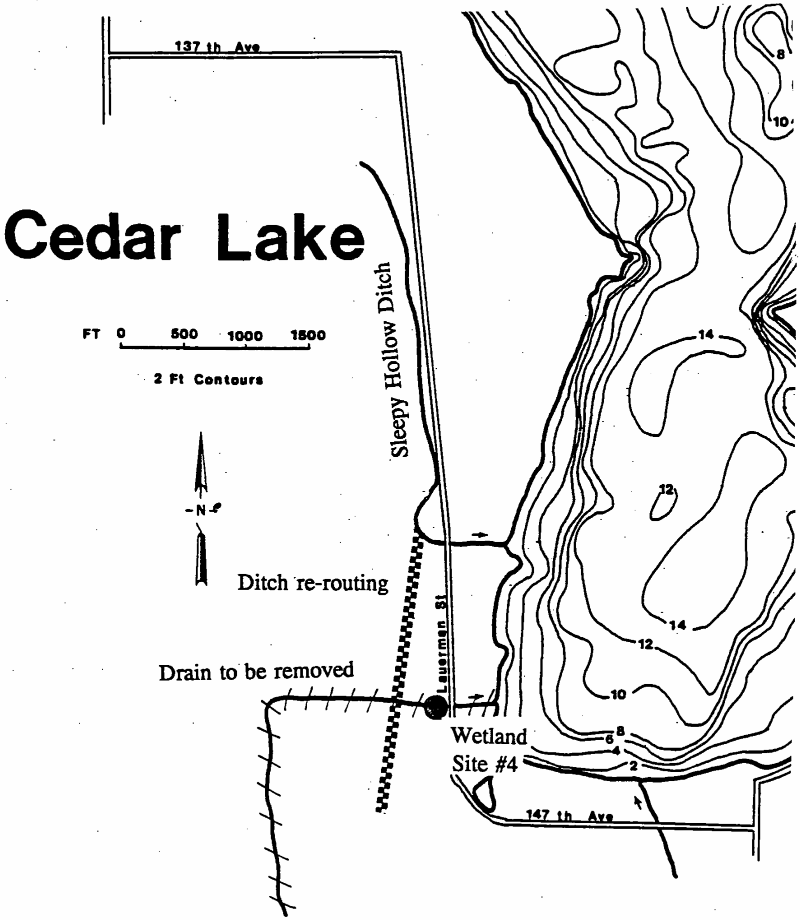

Figure 7-1. Options for rerouting Sleepy Hollow Ditch and removing wetland drains.

is needed to identify points of infiltration, exfiltration, and illegal connections. Until this is done, the success of all other management efforts to reduce nutrient loading to Cedar Lake is compromised.

7.4 WETLANDS TREATMENT

Cedar Lake Marsh, which drains approximately one-half of Cedar Lake's drainage basin, can be used more effectively to treat nonpoint sources of pollutants in runoff following the guidelines described in Section 6.4. The wetland area to drainage area is 5.7:1 which should afford optimal contact time for treatment of sheet runoff (Willenbring, 1985). To encourage sheet runoff through the wetland, all existing surface channels through Cedar Lake Marsh should be filled in. The following specific actions are recommended:

1. Fill in the constructed drainage ditch and remove any subsurface wetland drains at the northwest region of the wetland to encourage sheet flow through the wetland and increase contact time with wetland soils and vegetation (see Figure 7-1). The U.S. Fish and Wildlife Service has a wetlands restoration program in Indiana that assists landowners in restoring previously-drained wetlands. Since the program began in 1988, 350 wetlands have been restored across the state. For assistance or information, contact:

   U.S. Fish and Wildlife Service
   Bloomington Field Office
   718 North Walnut Street
   Bloomington, IN 47401

2. Direct any watershed flows away from the wetland area at Site 4 (see Figures 5-1 and 7-1). The wetland area at Site 4 is saturated with phosphorus and likely exports phosphorus to the lake.

3. Breach the old Monon Railroad grade in at least several places to the north and the south of the present breach to allow more even flow of runoff across the wetland.

4. To ensure long-term use of Cedar Lake Marsh as a sediment and nutrient filter, local and state officials should consider purchasing the wetlands.

5. As water levels even out across the wetland due to actions 1-3 above, wetland plants will self-seed or sprout from dormant seed banks and spread into areas now dominated by standing water. Therefore, we anticipate that no plantings will be required.

Any work within Cedar Lake Marsh will require a Section 404 Permit from the Corps of Engineers. The Corps should be contacted at least six months in advance of any proposed actions to allow them sufficient time to review the plan and the 404 Permit application. The U.S. Fish and Wildlife Service, the

Indiana Department of Natural Resources and the Indiana Department of Environmental Management should also be contacted regarding any additional permits or approvals required.

7.5 HOGPEN DITCH REROUTING

The AGNPS modeling showed that the rate of sediment and nutrient loading from the Hogpen Ditch watershed is less than that from the other subwatersheds. The additional water from this 764 acre watershed could aid in diluting existing lake water and in increasing the flushing rate of Cedar Lake. This will speed up the recovery of the lake. For example, the original Phase I Report calculated the flushing rate for Cedar Lake in "typical" years as 0.76 lake volumes per year. The addition of the Hogpen Ditch discharge (approximately 500 thousand m^3 per year) could increase the flushing rate to 0.82 volumes per year, a 7.9 percent increase. Because Hog Pen Ditch is located near Cedar Lake's outlet, "short circuiting" of the flow could lesson the dilutional effect of the additional input. Therefore, the northernmost point feasible should be selected for the location of the new Hog Pen Ditch inlet. Regardless of its location, some additional dilution of the high nutrients in the lake will occur.

Rerouting Hogpen Ditch back into its original channel will require the acquisition of a right-of-way or easement. Additional land should be acquired for construction of a small wetlands/sedimentation basin to treat the runoff before it enters Cedar Lake. Approximately 3.5 acres will be needed if the basin is sized at 0.05 percent of the drainage area (Jones and O'Reilly, 1986). Sedimentation basin costs vary widely and the best estimate can be calculated during the Design Study. Literature estimates for sedimentation basin costs vary from $5,200 to $120,000 per basin acre, depending on the design, basin size, and basin location (Pitt, 1989).

Increasing the discharge from Cedar Lake will not increase downstream flooding since Hogpen Ditch already discharges into Cedar Creek, Cedar Lake's outlet. By treating Hogpen Ditch discharge before it enters Cedar Lake, nutrient and sediment loads from the ditch will decrease over present levels. Nutrient mass loading from the lake to downstream areas could increase slightly due to the increased discharge. On balance, total nutrients discharged from the lake will eventually decrease as nutrient concentrations within the lake decrease due to expected NPS watershed controls.

7.6 SHORELINE EROSION CONTROLS

Shoreline erosion is an active process on some shoreline areas of Cedar Lake (Figures 7-2 to 7-4). In some areas, according to local sources, twenty feet of shoreline have been lost. Eroded, unstabilized shoreline areas can be stabilized in most cases by regrading and revegetating as described in Section 6.3. On steep banks, on points, and on shoreline areas along the southern end of the lake where wind-driven waves are most severe, structural controls such as rip rap may be needed.

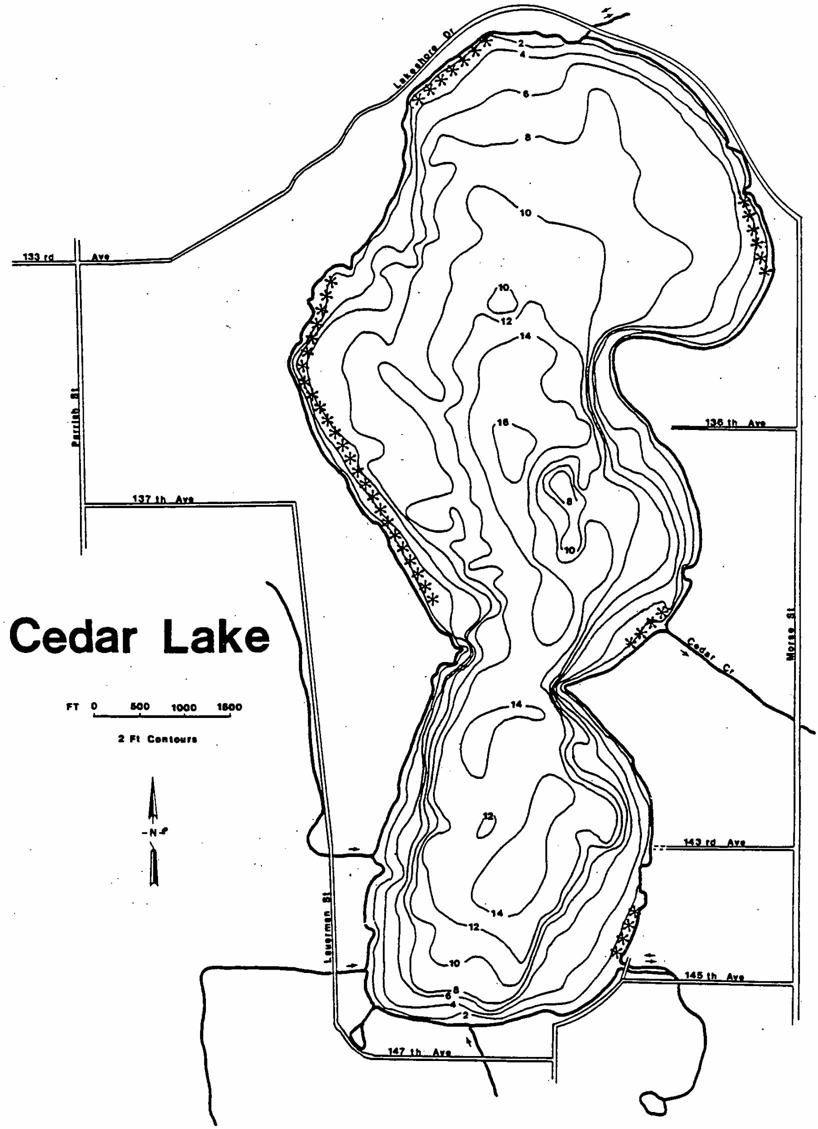

Figure 7-2. Locations of major areas of shoreline erosion.

Figure 7-3. Shoreline lost to erosion.

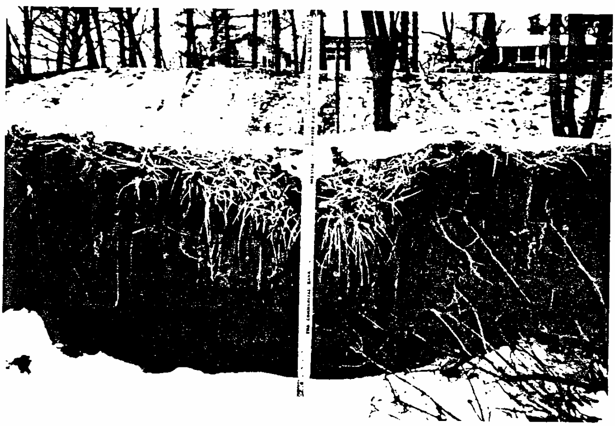

Figure 7-4. A three foot high vertical bank lies unprotected.

Attempts should be made to establish beneficial emergent and submerged aquatic vegetation in the littoral zone along eroding sections of shoreline. Rooted aquatic vegetation helps dampen wave energy and can provide many positive benefits for fish and aquatic organisms. Refer to Table 6.3 for guidance. The local Indiana DNR fisheries biologist is also a good source of assistance. We recommend a trial planting using the following scheme along several shoreline areas to test species effectiveness.

<u>Littoral Vegetation Planting Recommendation</u>

Shoreline to ankle-deep water	Reed canary grass
5" to 3' deep	Bullrush
Greater than 3' deep	wild celery and Sago pondweed

The physical forces caused by wave action limits plant survival in open lake areas. For example, in Lake Marion, South Carolina, aquatic macrophytes did not grow in areas where wind fetch exceeded 850 meters (2800 feet)(Harvey et al., 1987). Snow fencing can be placed along the lakeward edge of new plants to reduce the energy of waves and protect the plants until they become established. However, poor water transparency may limit the light available for submergent aquatic plants (wild celery and Sago pondweed) in Cedar Lake. The snow fence can also reduce suspended sediments, which reduce transparency, in the planted areas. Trial plantings in Cedar Lake will help evaluate the expected survival and effectiveness of aquatic vegetation buffers before full-scale planting is undertaken.

Additional shoreline protection is possible by implementing speed zones on Cedar Lake. By restricting boat speeds along the shoreline, the additional wave action generated by boats will not adversely impact the shoreline or shoreline vegetation plantings. No-wake zones are used on many Indiana Lakes to protect wetland areas and to prevent shoreline erosion.

7.7 CONTROLLING SEDIMENT RESUSPENSION

The resuspension of lake bottom sediments into the water column is a pervasive problem in Cedar Lake. Inorganic materials and plant organic matter never has a chance to permanently settle out of the water column. The shallow depth, long wind fetch, and motor boat activity all work to generate large waves and turbulence which keeps these materials suspended, thereby reducing transparency to levels which are consistently among the worst in any lake in Indiana. Of 42 lakes monitored regularly during 1989, Cedar Lake's mean July-August Secchi disk transparency (1.06 feet) ranked 41st (Jones et al., 1990).

Improving Cedar Lake's transparency will not be easy. Other than reducing algal production through watershed nutrient controls and reducing sedimentation through watershed erosion controls, there are two additional options: limiting motorboat speeds in shallow areas and dredging to increase the depth of the lake.

7.7.1 Boat Speed Restrictions

In the original Phase I Report, we reported that work in Florida (Yousef et al. 1978) found that induced waves from motorboats resuspended bottom sediments, increased turbidities, and increased phosphorus release. For example, a 60 hp motorboat could resuspend fine (0.05mm) sediments in Cedar Lake to a depth of 10 feet and larger particles (1.00 mm) to a depth of 5 feet (Figure 7-5). The effects of boat-induced turbulence appear to level off at about ten feet. Restricting motorboat speeds in water less than 10 feet deep (62 percent of Cedar Lake's surface area) would reduce resuspension due to 60 hp and smaller motorboats, but this will cause a major impact on the recreational use of the lake. Tough choices must be made by the local officials.

Because we have already recommended reducing motorboat speeds near shore to help reduce shoreline erosion, we also recommend boat speed restrictions to reduce the resuspension of bottom sediments. However, it is our opinion that wind-induced turbulence is the biggest cause of sediment resuspension and <u>excessive</u> boat speed restrictions in Cedar Lake will not result in significant improvements in transparency. Therefore, we recommend that a no-wake zone be implemented in a zone extending from the shoreline to a depth of six feet (see Figure 2-2). This represents approximately 55 percent of Cedar Lake's surface area (see Figure 1-3, Phase I Report). Marker buoys should be used to designate the no-wake zones. Public education through signs at boat ramps will further inform the boating public. This restriction should be implemented for a one-year trial period, during which regular and extensive transparency monitoring should be conducted. The effects of the restrictions can be reviewed after the first year.

7.7.2 Dredging for Increased Depth

Cedar Lake has always been shallow due to the original size and shape of the ice block that formed the lake. The original depth of the lake reached a maximum of 10 meters in the center lobe, nearly 9 meters in the south lobe, and only 7.5 meters in the north lobe. Approximately five meters of sediment has filled in the deepest portions of each of these lobes (see Figure 2-24, p. 55, Phase I Report).

In the original Phase I Report we evaluated dredging for nutrient control in Cedar Lake and concluded that it would not reduce phosphorus release sufficient to result in appreciable improvements in algal production (see Section 6.9.1, pp 195-197, Phase I Report). While this conclusion still holds, we believe that sediment resuspension due to wind will continue to be a problem as long as Cedar Lake remains as shallow as it is. Deepening the lake sufficiently to allow thermal stratification in the summer would prevent wind-resuspension of bottom sediments. Predicting this depth for Cedar Lake is not easy.

Stefan and Hanson (1980) found that an eight meter depth was sufficient to prevent sediment mixing in the Fairmont Lakes in Minnesota. However, a recent evaluation of models used to predict mixing depth found that the

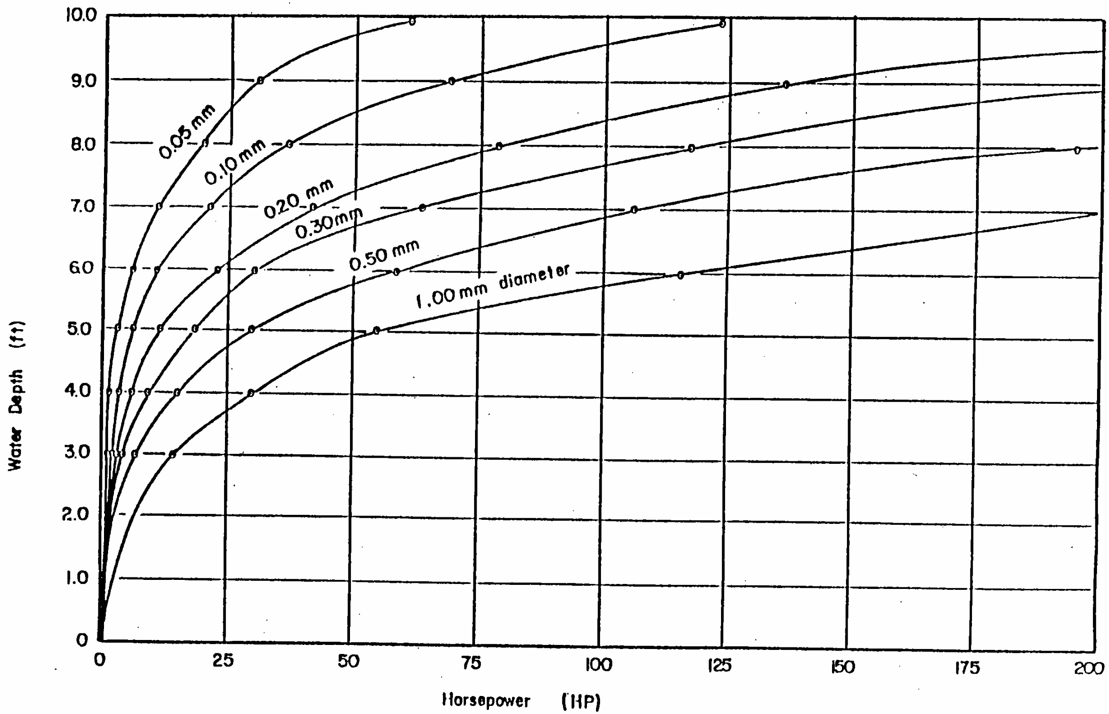

Figure 7-5. Sediments resuspended by motorboats as a function of depth and motor size. Source: Yousef et al. (1978).

maximum effective length (MEL) of a lake is the most important variable controlling mixing depth (Hanna, 1990). Hanna's model is:

$$\text{Log THER} = 0.336 \text{ Log MEL} - 0.245$$

where THER = thermocline (mixing) depth.

The MEL for Cedar Lake's center basin, assuming winds either out of the due north or due south, is approximately 1600 meters. Using Hanna's model, the mixing depth would be 6.8 meters (22.5 feet). Thus, the water depth in the center basin would have to be deeper than this to prevent mixing and resuspension of the sediments.

At a minimum, an average of three meters of sediment would need to be removed from the center basin to reach the 6.8 meter water depth. For example, if a 35 hectare (86 acre) area of the center basin was dredged to a depth of 6.8 meters, approximately 1.05 million m^3 of sediment would have to be dredged. Using an average cost of $3.00 per cubic meter of sediment dredged (K. Klene, pers. comm.), it would cost in excess of $3 million just to remove the sediments. While this could keep 86 acres of lake sediments from being resuspended by the wind, an additional 695 acres (89 percent) would still be subject to wind mixing.

These are admittedly just crude estimates. A more detailed estimate is beyond the scope of this study. While it may be technologically feasible to deepen all of Cedar Lake to prevent sediment resuspension, the financial costs would be astronomical and not feasible. Therefore, we cannot recommend dredging.

7.8 OUTLET STRUCTURE REPAIRS

In early January, 1991, emergency repairs were required at the Cedar Lake outlet structure (dam) to repair a hole 5 feet long by 2 feet wide by 3 feet deep. The outlet structure maintains the lake elevation at 693 feet MSL. There is continuing confusion over ownership of the land on which the outlet structure sits, and this leaves the maintenance responsibility for the structure unresolved.

The importance of the outlet structure to Cedar Lake's maintenance is unquestioned. The present structure should be permanently repaired or replaced with a new structure. The repaired or new structure must include a barrier to prevent fish, especially carp, from entering Cedar Lake from Cedar Creek downstream when water levels are high. Such a fish barrier was recommended in the 1987 IDNR Fish Management Report (Appendix A). The bottom-feeding carp are notorious for resuspending sediments and uprooting aquatic vegetation (Shapiro et al., 1975; Lamarra, 1975). The success of vegetation plantings requires that carp be eliminated from and denied access to Cedar Lake.

Indiana Department of Natural Resources fisheries biologists should be consulted during the Design Study to get their input on fish barriers.

7.9 FISHERIES RENOVATION

In the initial Phase I report, we recommended fisheries renovation and restocking with piscivore-dominated mix as a biomanipulation technique. Since that time, a significant amount of effort has been made in managing Cedar Lake's fisheries (see Section 3.3). However, in the 1987 Fish Management Report, carp constituted nearly 63% of the fish biomass collected by the IDNR. Once a fish barrier is in place at the Cedar Creek outlet, an aggressive carp eradication program must be implemented to help insure the success of this comprehensive lake enhancement program on Cedar Lake.

7.10 RECOMMENDATIONS SUMMARY

Water quality in Cedar Lake can be enhanced by the implementation of the following actions:

1. Agricultural best management practices.
2. Enhancement of Cedar Lake Marsh's filtering ability.
3. Correction of the wastewater system surging and overflows.
4. Urban best management practices.
5. Urban erosion and stormwater control ordinances.
6. Lakeshore erosion controls.
7. Motorboat speed zones.
8. Rerouting Hogpen Ditch drainage into Cedar Lake with appropriate pretreatment.
9. Outlet structure repair or replacement, including a fish barrier.
10. Comprehensive carp management program.

8.0 ENVIRONMENTAL EVALUATION

Appendix A of the final regulation establishing operating rules and procedures for the Clean Lakes Program includes a fourteen question environmental evaluation which must be completed before a Section 314 Phase II Implementation grant can be awarded. The questions are presented here along with our responses.

1. "Will the proposed project result in the displacement of any people?"

   It is not anticipated that any people will have to be moved as a result of this project.

2. "Will the proposed project deface existing residences or residential areas? What mitigative actions such as landscaping, screening, or buffer zones have been considered? Are they included?

   No residences or residential areas will be defaced as a result of this project. Construction activity at the outlet structure at Cedar Creek may involve digging and the temporary parking of construction vehicles in that vicinity. Rerouting Hogpen Ditch and constructing a sedimentation basin will require an easement or land purchase. Details of the design and landscaping plan will be presented in the Design Plan following the Lake Enhancement Design Study.

3. "Will the proposed project be likely to lead to a change in established land use patterns, such as increased development pressure near the lake? To what extent and how will this change be controlled through land use planning, zoning, or through other methods?"

   Any improvement in the water quality of Cedar Lake may create increased use of the lake for recreational purposes. Increased development along the lakeshore is unlikely since development is presently near saturation in this area. A zoning ordinance for Cedar Lake was adopted in 1980. The lead local and state agency involved in the implementation of this program should coordinate plans with the Cedar Lake Plan Commission.

4. "Will the proposed project adversely affect a significant amount of prime agricultural land or agricultural operations on such land?"

   No agricultural land will be affected by the proposed project.

5. "Will the proposed project result in a significant adverse effect on parkland, other public land, or lands of recognized scenic value?"

   No significant impacts are anticipated on parkland, other public land, or lands of recognized scenic value as a result of this project. Some increased use of local parklands could occur if an improved Cedar Lake attracts a larger user population.

6. "Has the State Historical Society or State Historical Preservation Officer been contacted by the grantee? Has he responded, and if so, what was the nature of that response? Will the proposed project resu in a significant adverse effect on lands or structures of historic, architectural, archaeological, or cultural value?"

The State Historical Society Historical Preservation Officer has not been contacted in this study. It is not anticipated that any land or structures of historic, architectural, archaeological, or cultural value need be adversely affected by this project.

7. "Will the proposed project lead to a significant long-range increase in energy demands?"

It is not anticipated that the project will lead to any increases in energy demand, unless a cleaner Cedar Lake will attract tourists from greater distances. This could possibly lead to greater consumption of automobile fuels.

8. "Will the proposed project result in significant and long range adverse changes in ambient air quality or noise levels? Short term?"

No significant long term or short term changes in ambient air quality or noise levels are expected to result from the project.

9. "If the proposed project involves the use of in-lake chemical treatment, what long and short term adverse effects can be expected from the treatment? How will the project recipient mitigate these effects?"

No in-lake chemical treatments are recommended in this plan. Should a selective fish toxicant such as rotenone be used, it will be applied by the Indiana Department of Natural Resources according to their prescribed procedures.

10. "Does the proposal contain all the information that EPA requires in order to determine whether the project complies with Executive Order 11988? Is the proposed project located in a floodplain? If so, will the project involve construction of structures in the floodplain? What steps will be taken to reduce the possible effects of flood damage to the project?"

Modification of the outlet structure on Cedar Creek is proposed to prevent rough fish from entering Cedar Lake from Cedar Creek. Deepening the plunge pool on the downstream side of the dam or installing a fish barrier on the existing dam would involve construction in the floodplain of Cedar Creek and therefore would require the appropriate permit(s) from the Indiana Department of Natural Resources. Plans for such modifications would be developed in conjunction with the Indiana DNR using appropriate technologies and safeguards.

Installation of shoreline erosion controls will require an Indiana DNR permit if such work proceeds below Cedar Lakes established ordinary high water line. All IDNR guidelines for minimizing flood damage should be adhered to.

11. "If the project involves physically modifying the lake shore or its bed or its watershed, by dredging, for example, what steps will be taken to minimize any immediate and long term adverse effects of such activities? When dredging is employed, where will the dredged materials be deposited, what can be expected and what measures will the grantee employ to minimize any significant adverse impacts from its deposition?"

Dredging and disposal plans are discussed in Section 6.3 of this report. However, since dredging was not determined to be technologically feasible for improving Cedar Lake, it is not being recommended. Lakeshore erosion controls must meet IDNR permit requirements (see #10 above).

12. "Does the proposed project proposal contain all information that EPA requires in order to determine whether the project complies with Executive Order 11990 on wetlands? Will the proposed project have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species?. How significant is this impact in relation to the local or regional critical habitat needs? Have actions to mitigate habitat destruction been incorporated into the project? Has the recipient properly consulted with appropriate State and Federal Fish, game and wildlife agencies and with the U.S. Fish and Wildlife Service? What were their replies?"

Recommendations from this study strive to protect wetlands adjacent to Cedar Lake from any degradation. The removal of old wetland drainage ditches and tiles to restore previous wetland functions will require work in Cedar Lake Marsh. This work will require a Corps of Engineers Section 404 permit, as advised in Section 7.4 previously. The U.S. Fish and Wildlife Service will be contacted for assistance before any wetland work begins.

No endangered species are known to occur in Cedar Lake Marsh or the lake itself. However, a fisheries renovation of Cedar Lake could include treating both Cedar Lake Marsh and the north wetland with rotenone or a similar poison. Fisheries specialists with the Indiana DNR have been consulted and they will conduct the renovation if it is implemented.

13. "Describe any feasible alternatives to the proposed project in terms of environment impacts, commitment of resources, public interest and costs and why they were not proposed.

The environmental impacts, costs, public interest, and resource requirements of all feasible alternatives are described in Chapter 6 of the original Phase I report (Echelberger et al., 1984).

14. "Describe other measures not discussed previously that are necessary to mitigate adverse environmental impacts resulting from the implementation of the proposed project."

Measures designed to mitigate adverse environmental impacts resulting from this project are described in Chapters 6 and 7.

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APPENDIX A:

1987 Fish Management Report

CEDAR LAKE
Lake County
Fish Management Report
1987

INTRODUCTION

Cedar Lake is a 781 acre natural lake located in Lake County in the extreme northwest corner of Indiana. Since the late 1940's, the lake has suffered from high bacterial counts and heavy algal blooms. Many of Cedar Lake's problems were attributed to the large number of residential units built in an area with inadequate soils for individual septic systems.

The lake's fish population was first surveyed in 1964 in an effort to provide fisheries information, along with a report by the U.S. Public Health Service and the Indiana Stream Pollution Control Board, that would be useful in formulating plans for the lake and surrounding area. The fish population in 1964 was found to be undesirable and the lake was renovated in the fall of 1966. Lake Dalecarlia, 193 acres, was also renovated at this time because of its direct connection with Cedar Lake (Map 1).

Benefits of the 1966 fish eradication project were short lived. Bass, bluegill, and crappie failed to maintain populations that provided fishing acceptable to most anglers. By 1974 undesirable fish, mainly gizzard shad and carp, once again dominated the fish population accounting for more than 95% of the survey catch (Robertson 1974). The continued eutrophic state of Cedar Lake helped the undesirable fish reestablish themselves. It appeared that until the water quality of the lake improved substantially, little could be done to improve the lake's fish population. The 1974 fish survey report recommended Cedar Lake be resurveyed when the sewage system, begun in 1972, was completed. Installation of the lakewide sewage system was complete by late 1975. An additional fishery survey in 1976 again found the fish population dominated by undesirable fish (Robertson 1977).

During the winter of 1976-1977, Cedar Lake experienced a winterkill that apparently eliminated the lake's gizzard shad as no gizzard shad were collected by gill netting and electrofishing in June 1977. The 1976 report also noted that carp and shad from Cedar Creek had been observed entering Lake Dalecarlia over the dam, and subsequently entering Cedar Lake.

In 1978, the Indiana Legislature appropriated funds to determine the feasibility of restoring Cedar Lake. Indiana University began work on this project in 1979. An additional fishery survey was conducted by the I.D.N.R. in 1979 to furnish current fishery information for the feasibility study. Recommendations of the Cedar Lake Restoration Feasibility Study, completed in January 1984, included:

1. Lake and watershed management practices.
2. Fish eradication - conducted by the I.D.N.R. at an estimated cost of $150,000.
3. Fish restocking - conducted by the I.D.N.R.
4. Outlet improvements - to prevent rough fish from reentering Cedar Lake.
5. Alum treatment - to reduce phosphorous concentrations and suspended sediment at an estimated cost of $250,000.
6. Motorboat speed reduction - trolling speed only from ice-out to July 1 of the treatment year to prevent turbulence from disturbing the alum floc.
7. Ban on live bait fishing - to prevent the inadvertent introduction of undesirable fish into Cedar Lake.

Implementation of the above recommendations has not occurred due to a lack of funding.

RESULTS OF 1987 FISHERY SURVEY

On June 15-18, 1987 a fishery survey was conducted to determine the present status of the fish population of Cedar Lake. An additional hour of nighttime electrofishing was conducted October 27. We collected 1,315 fish representing

15 species. Relative abundance of the major species by number was: yellow perch 39%, carp 26%, black crappie 13%, bluegill 9%, and channel catfish 2%. Relative abundance of the major species by weight was: carp 63%, yellow perch 13%, goldfish 6%, channel catfish 5%, black crappie 4% and bluegill 4%.

Yellow perch ranked number one in abundance by number. of the 516 yellow perch collected, 30% were 8 inches or larger. Most of the perch collected were age III+ fish from the 1984 year class. Some age II+ fish were also collected. Weights were average while growth rates were above average.

Carp, number two in abundance by number, dominated the fish population by weight. Carp made up nearly 63% of the survey catch by weight. The 345 carp collected ranged in length from 7 to 22½ inches. Age I+ through V+ carp were identified.

Black crappie ranked third in abundance by number. One hundred and sixty eight black crappie were collected that ranged in length from 3½ to 10 inches. Nearly 22% of these fish were 8 inches or longer. Weights and growth were average.

Bluegill ranked fourth in abundance by number. The 120 bluegill collected ranged in length from 2-8½ inches. Approximately 82% of the bluegill collected were 6 inches or longer and almost 30% were 7½ inches or longer. Bluegill weights and growth rates were both above average.

Thirty two channel catfish ranging in length from 13 to 19 inches were collected. Catfish weights were average.

Other game fish collected included six white crappie, three northern pike, and three largemouth bass.

Water conditions noted June 15, 1987 included an algal bloom; water color was brownish-green with a secchi disk reading of 1 foot 4 inches. Surface and bottom alkalinity were 136 and 119 respectively and the pH of the water was 9.5. Many fish were observed with clouded eyes and fungus on their tails. Lernaea, a parisitic copepod, was also noted on many fish.

DISCUSSION

In the 1987 survey, sport fish only made up 64% of the total population by number and 29% by weight. As in previous surveys since the early 1970's, undesirable species dominated the lake's fish population (Table 1). Carp accounted for 63% of the weight of all fish collected in 1987. Gizzard shad, abundant prior to the winterkill of 1976-77, are again present in Cedar Lake although in small numbers. The gizzard shad population in this highly eutrophic lake is expected to expand.

Yellow perch, not previously recorded in surveys conducted since the 1966 renovation, are now the most numerous fish in Cedar Lake. Yellow perch, black crappie and bluegill are providing fairly good angling opportunities. Channel catfish, white crappie, northern pike and largemouth bass are present but in low numbers. Despite three hours of nighttime electrofishing, only three largemouth bass were collected. Similar low bass densities were noted in each of the last four surveys. The reasons for such a poor quality bass population are unknown.

Water quality remains questionable. High pH readings and high turbidities were noted at the time of the survey, along with a dense algal bloom. Although the area around the lake has been on a sewage treatment system since 1976, the low annual water exchange rate of Cedar Lake may be reducing or delaying improvements to water quality. The resuspension of bottom sediment caused by wind, motorboats, and bottom dwelling fish may also be contributing to the continuing water quality problems of this relatively shallow lake.

Due to a lack of funds through the Clean Lakes Program, the recommendations of the Cedar Lake Feasibility Study have not been implemented. In an attempt to improve fishing opportunities, the Cedar Lake Chamber of Commerce stocked 4,400 hybrid striped bass in August of 1987. The establishment of hybrid stripers may provide additional predation in this predator poor fish population.

The Cedar Lake Chamber of Commerce, the Town of Cedar Lake, and the Indiana Department of Natural Resources are currently involved in a project that will add needed facilities at the state access site on the north end of Cedar Lake.

RECOMMENDATIONS

Cedar Lake is located in Lake County, the second most highly populated county in Indiana. By 1900 an estimated 843,700 people will be living in this county. The Governor's Water Resource Study Commission estimates that 43% of area residents participate in fishing (The Indiana Water Resource, 1980). It is obvious that improving fishing at Cedar Lake, the largest publicly accessible lake within Lake County, would yield tremendous benefits.

In 1966, the Division of Fish and Wildlife attempted an improvement project by itself and the results were disappointing. To successfully improve fishing at Cedar Lake, more than fish eradication and restocking needs to occur. Improvements in water quality through the permanent reduction of nutrients in the water column should be accomplished before another fish eradication is attempted. In addition, the fish population of Cedar Lake and/or Lake Dalecarlia must be permanently separated from fish populations in downstream Cedar Creek. Presently, fish from Cedar Creek can enter Dalecarlia Lake over either of the two dams or by traveling upstream through a marsh on the southeast corner of Dalecarlia Lake (Map 2).

Efforts to rehabilitate Cedar Lake should continue with a reexamination of the Cedar Lake Restoration Feasibility Study by a team of representatives from the following public agencies: The Indiana Department of Environmental Management, Indiana Division of Water, Indiana Division of Fish and Wildlife, Indiana Division of Soil Conservation, the U.S. Environmental Protection Agency, Indiana University, Ball State University, the Town of Cedar Lake and any other interested local, state, or federal agency. Once a definite plan has been agreed upon, funding for the project should be pursued.

Until a schedule for a comprehensive restoration project has been determined, the Division of Fish and Wildlife should attempt to improve the predator fish population of Cedar Lake by supplementally stocking hybrid striped bass. These fish are fast growing and may provide fishing opportunities in their second year of growth. Spring electrofishing and fall gill netting should be conducted annually to monitor the predator population of the lake.

Submitted by: Bob Robertson, Fisheries Biologist
Date: 2/25/88

Approved by: Gary Hudson
Gary Hudson, Fisheries Supervisor

William D. James
William D. James, Chief of Fisheries
Date: 2/29/88

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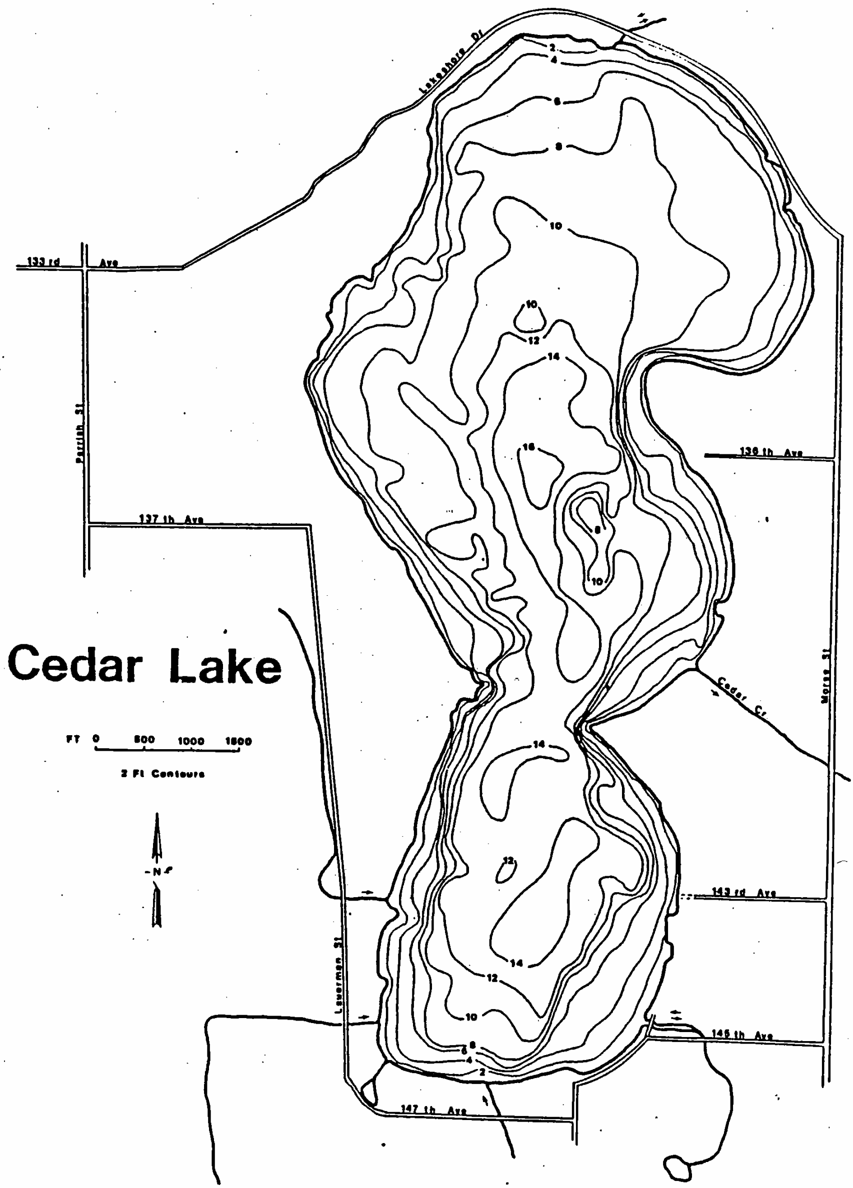
SPECIES AND RELATIVE ABUNDANCE OF FISHES COLLECTED BY NUMBER AND WEIGHT

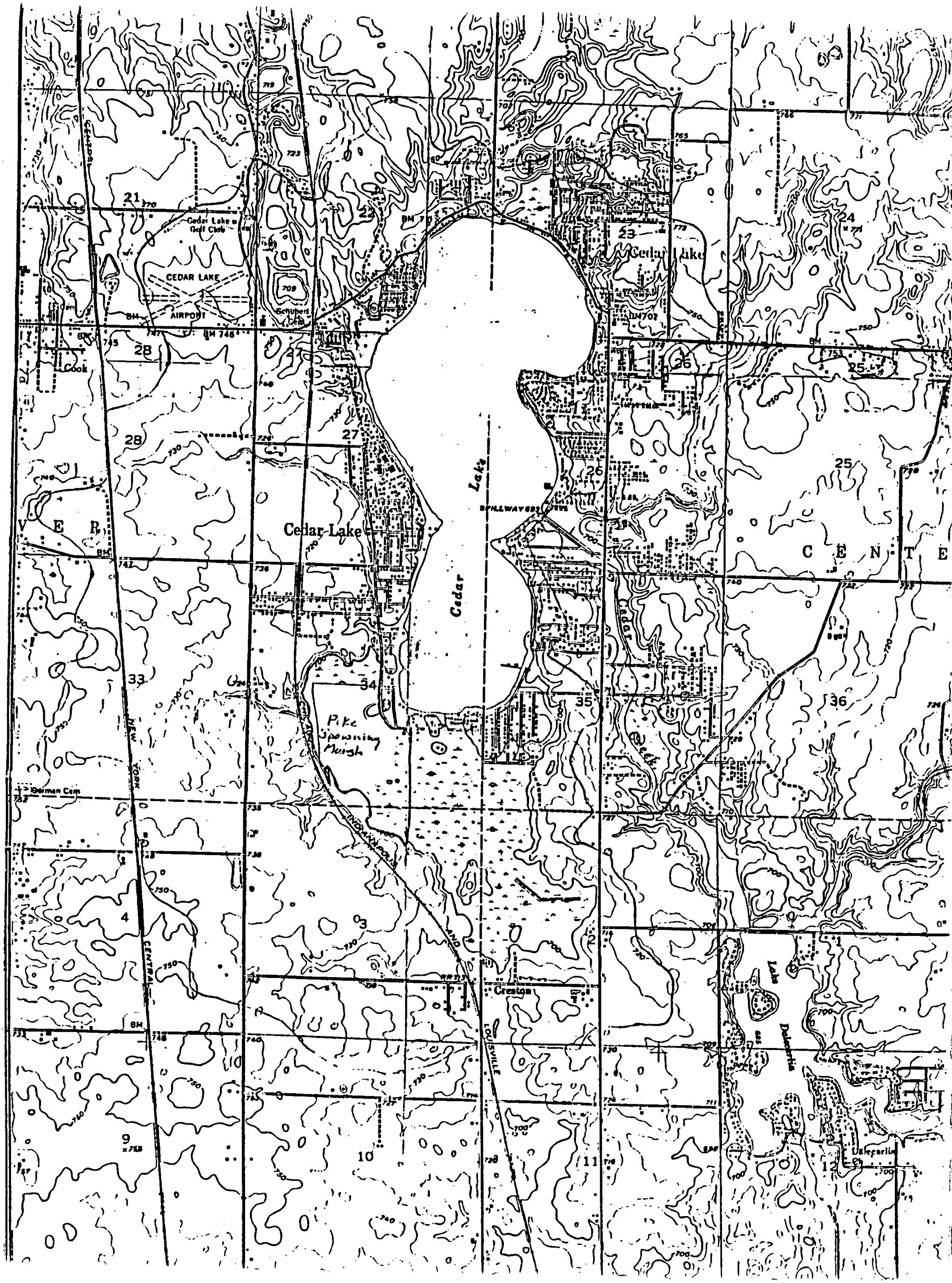
*COMMON NAME OF FISH	NUMBER	PERCENT	LENGTH RANGE (Inches)	WEIGHT (Pounds)	PERCENT
Yellow perch	516	39.2	5.9 - 8.9	100.17	12.9
arp	345	26.3	7.0 - 22.4	488.47	62.9
Black crappie	168	12.8	3.7 - 10.1	33.53	4.3
Bluegill	120	9.1	2.0 - 8.5	32.68	4.2
Pumpkinseed	45	3.4	3.0 - 5.7	5.06	0.7
Goldfish	37	2.8	10.5 - 15.8	46.08	5.9
Channel catfish	32	2.4	13.0 - 19.0	37.44	4.8
Gizzard shad	21	1.6	7.5 - 14.5	8.82	1.1
Green sunfish	15	1.1	3.3 - 4.6	0.73	0.1
White crappie	6	0.5	5.6 - 8.9	1.34	0.2
Northern pike	3	0.2	25.4 - 26.5	12.85	1.7
Largemouth bass	3	0.2	6.1 - 15.7	5.40	0.7
Bowfin	2	0.2	13.3 - 13.9	2.14	0.3
own bullhead	1	0.1	8.6	.30	< 0.1
White sucker	1	0.1	13.9	1.30	0.2
Total	1,315			776.31	

Table 1. Cedar Lake survey catches 1976-1987.

Species	1976 Number(%)	1976 Weight(%)	1977 Number(%)	1977 Weight(%)	1979 Number(%)	1979 Weight(%)	1987 Number(%)	1987 Weight(%)
Gizzard shad	61.8	12.7	-	-	-	-	1.6	1.1
Carp	13.2	23.8	23.5	-	38.9	80.3	26.3	62.9
Goldfish	7.8	15.2	12.7	-	0.5	0.7	2.8	5.9
Bluegill	6.5	1.7	20.5	-	5.3	1.0	9.1	4.2
Black crappie	6.3	1.5	37.7	-	42.6	10.2	12.8	4.3
Channel catfish	1.8	25.5	-	-	9.5	5.4	2.4	4.8
Largemouth bass	1.0	5.5	2.2	-	0.8	0.4	0.2	0.7
Northern pike	0.1	6.1	-	-	1.0	1.9	0.2	1.7
Yellow perch	-	-	-	-	-	-	39.2	12.9
Total catch	2,288		268		399		1,315	
	July 6-8, '76 Electrofishing = 2 hrs. (night) Gill nets = 8 lifts Trap nets = 0 Regular survey		June 9-10, '77 Electrofishing = 1 hr. (day) Gill nets = 4 lifts Trap nets = 0 Follow up survey to investigate '76-'77 winterkill		August 20-21, '79 Electrofishing - 2 hrs. (1 day, 1 night) Gill nets = 2 lifts Trap nets = 2 lifts Survey conducted for Indiana University as part of the Cedar Lake Restoration Feasibility Study.		June 15-18, Oct. 27, '87 Electrofishing = 3 hrs. (night) Gill nets = 10 lifts Trap nets - 11 lifts Regular survey	


Cedar Lake
FT 0 500 1000 1500
2 Ft Contours
N
Lakeshore Dr
133 rd Ave
Parrish St
137 th Ave
136 th Ave
Morse St
Cedar Cr
143 rd Ave
145 th Ave
147 th Ave
Lauerman St

MAP 1.



Cedar Lake Golf Club
CEDAR LAKE
AIRPORT
Cook
German Cem
Cedar Lake
Cedar Lake
Cedar Lake
SPILLWAY
Cedar
Creek
Pike Spawning Marsh
Creston
NEW YORK CENTRAL
LOUISVILLE
Lake Dalecarlia
Dalecarlia
V E R
C E N T E
21
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12

LAKE SURVEY REPORT

State Form 24753R

Type of survey: ☐ Initial survey ☒ Re-survey

Lake name	County	Date of survey (Month, day, year)
Cedar Lake	Lake	June 15-18,Oct. 27, '8

Biologist's name	Date of approval (Month, day, year)
Bob Robertson	2/29/88 G.H.

LOCATION

Quadrangle name	Range	Section
Cedar Lake	9W	22,23,26,27,34,35

Township name	Nearest town
34N	Crown Point, IN

ACCESSIBILITY

State owned public access site	Privately owned public access site	Other access site
Located on north shore.		

Surface acres	Maximum depth	Average depth	Acre feet	Water level	Extreme fluctuations
781	16 Feet	9 Feet	6,749	692.9 MSL	2.48 feet

Location of benchmark: At spillway, elev. 695.83 MSL

INLETS

Name	Location	Origin
Cedar Lake has five inlet streams; four are intermittent.		

OUTLET

Name	Location
Cedar Creek	east side

Water level control: Concrete dam with fixed crest.

POOL	ELEVATION *(Feet MSL)*	ACRES
TOP OF DAM		
TOP OF FLOOD CONTROL POOL		
TOP OF CONSERVATION POOL		
TOP OF MINIMUM POOL		
STREAMBED		

Bottom type:
- ☐ Boulder
- ☐ Gravel
- ☒ Sand
- ☒ Muck
- ☐ Clay
- ☐ Marl

Watershed use: Heavily residential with some commercial establishments. Some areas of marshland, forest and farms.

Development of shoreline: 95% residential.

Previous surveys and investigations: Fisheries surveys in 1964, 1969, 1971, 1974, 1976, 1977, 1979. Lake mapping 1958.

SAMPLING EFFORT

ELECTROFISHING	Day hours	Night hours 3	Total hours 3
TRAPS	Number of traps 3/1	Hours 72/48	Total hours 264*
GILL NETS	Number of nets 4/2	Hours 48/24	Total hours 240*

PHYSICAL AND CHEMICAL CHARACTERISTICS

Color Brownish green	Turbidity 1 Feet 4 Inches (SECCHI DIS

TEMPERATURE

DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°
SURFACE	80.6	40		80	
2	79.7	42		82	
4	78.8	44		84	
6	78.8	46		86	
8	77.0	48		88	
10	75.2	50		90	
12	75.2	52		92	
14	74.3	54		94	
16	74.3	56		96	
18		58		98	
20		60		100	
22		62			
24		64			
26		66			
28		68			
30		70			
32		72			
34		74			
36		76			
38		78			

DISSOLVED OXYGEN (D.O.) - TOTAL ALKALINITY - pH

DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	Comments:
SURFACE	9.4	136	9.5	45				* 11 trap net
5	9.0			50				lifts; 10 gil
10	5.0			55				net lifts.
15	1.0	119	9.5	60				
20				65				
25				70				
30				75				
35				80				
40								

*ppm = parts per million

COMMON SPECIES OF AQUATIC PLANTS			
COMMON NAME OF PLANT	SCIENTIFIC NAME OF PLANT	DEPTH FOUND	PERCENT OF LAKE COVERED
Emergent:			
Spatterdock	Nuphar advena		5%
Submergent:			
Eelgrass	Vallisneria americana		5%
Algae	Planktonic		

Comments

Rooted aquatic vegetation is not a problem, however, extensive algae blooms are common. These blooms oftentimes reach nuisance densities.

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: (species) YELLOW PERCH

TOTAL LENGTH (Inches)	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT (Pounds)	AGE OF FISH	TOTAL LENGTH (Inches)	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT (Pounds)	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0					15.5				
2.5					16.0				
3.0					16.5				
3.5					17.0				
4.0					17.5				
4.5					18.0				
5.0					18.5				
5.5					19.0				
6.0	12	2.3	0.09	II+	19.5				
6.5	57	11.1	0.12	II+,III+	20.0				
7.0	117	22.7	0.17	III+	Total	516			
7.5	177	34.3	0.19	III+					
8.0	108	20.9	0.23	III+					
8.5	39	7.6	0.26	III+					
9.0	6	1.2	0.31	III+					
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

ELECTROFISHING CATCH	2	GILL NET CATCH	513	TRAP NET CATCH	1

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* CARP

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5	6	1.7	1.38	III+
1.5					15.0	8	2.3	1.85	III+
2.0					15.5	38	11.0	1.74	III+
2.5					16.0	29	8.4	1.74	III+
3.0					16.5	24	7.0	2.14	III+,IV+
3.5					17.0	28	8.1	2.28	III+,IV+
4.0					17.5	16	4.6	2.72	IV+
4.5					18.0	9	2.6	2.79	IV+
5.0					18.5	7	2.0	3.26	IV+
5.5					19.0	9	2.6	3.04	V+
6.0					19.5	8	2.3	3.51	V+
6.5					20.0	1	0.3	4.38	-
7.0	4	1.2	.16	I+	20.5	1	0.3	3.60	-
7.5	5	1.5	.16	I+					
8.0	14	4.1	.31	I+	21.5	1	0.3	3.64	
8.5	30	8.7	.31	I+,II+					
9.0	34	9.9	.40	I+,II+	22.5	1	0.3	5.10	
9.5	27	7.8	.46	II+	Total	345			
10.0	16	4.6	.53	II+					
10.5	21	6.1	.63	II+					
11.0	5	1.5	.67	II+					
11.5									
12.0									
12.5									
13.0									
13.5									
14.0	3	0.9	1.28	III+					

ELECTROFISHING CATCH	106	GILL NET CATCH	183	TRAP NET CATCH	56

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* BLACK CRAPPIE

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0					15.5				
2.5					16.0				
3.0					16.5				
3.5	1	0.6	.04	I+	17.0				
4.0					17.5				
4.5	5	3.0	.04	I+	18.0				
5.0	17	10.1	.06	I+	18.5				
5.5	21	12.5	.10	I+	19.0				
6.0	6	3.6	.11	I+,II+	19.5				
6.5	6	3.6	.17	I+,II+	20.0				
7.0	12	7.1	.22	II+	Total	168			
7.5	25	14.9	.25	II+,III+					
8.0	39	23.2	.29	III+					
8.5	22	13.1	.33	III+					
9.0	7	4.2	.38	III+,IV+					
9.5	4	2.4	.47	IV+					
10.0	3	1.8	.50	IV+					
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

ELECTROFISHING CATCH	25	GILL NET CATCH	99	TRAP NET CATCH	44

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* BLUEGILL

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0	1	0.8	-	I+	15.5				
2.5	1	0.8	.01	I+	16.0				
3.0	1	0.8	.02	I+	16.5				
3.5					17.0				
4.0					17.5				
4.5	3	2.5	.07	II+	18.0				
5.0	3	2.5	.09	II+	18.5				
5.5	13	10.9	.14	II+	19.0				
6.0	12	10.1	.19	III+	19.5				
6.5	30	24.4	.24	III+	20.0				
7.0	23	19.3	.31	IV+	Total	120			
7.5	16	13.5	.39	IV+					
8.0	15	12.6	.42	V+,VI+					
8.5	2	1.7	.48	VII+					
9.0									
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

ELECTROFISHING CATCH	6	GILL NET CATCH	0	TRAP NET CATCH	114

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* CHANNEL CATFISH

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5	5	15.6	.90	
1.5					15.0	1	3.1	.92	
2.0					15.5	6	18.8	1.30	
2.5					16.0	3	9.4	1.28	
3.0					16.5	4	12.5	1.60	
3.5					17.0				
4.0					17.5	2	6.3	1.81	
4.5					18.0				
5.0					18.5				
5.5					19.0	1	3.1	2.64	
6.0					19.5				
6.5					20.0				
7.0					Total	32			
7.5									
8.0									
8.5									
9.0									
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0	2	6.3	.75						
13.5	3	9.4	.69						
14.0	5	15.6	.83						

ELECTROFISHING CATCH	0	GILL NET CATCH	32	TRAP NET CATCH	0

Species: Yellow perch	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE					
			I	II	III	IV	V	VI
	1986	-						
	1985	6	2.2	4.7				
	1984	26	2.6	5.2	7.0			
	AVERAGE LENGTH		2.4	5.0	7.0			
	NUMBER AGED		32	32	26			

Species: Black crappie	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE					
			I	II	III	IV	V	VI
	1986	12	3.6					
	1985	11	2.6	5.6				
	1984	13	2.5	5.9	7.6			
	1983	3	2.1	5.1	7.7	8.9		
	AVERAGE LENGTH		2.7	5.5	7.7	8.9		
	NUMBER AGED		39	27	16	3		

Species: Bluegill	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE					
			I	II	III	IV	V	VI
	1986	1	1.6					
	1985	9	1.2	4.1				
	1984	10	0.8	2.9	5.0			
	1983	7	1.2	3.6	5.4	6.4		
	1982	3	0.8	3.4	5.8	6.8	7.5	
	AVERAGE LENGTH		1.1	4.7	5.4	6.6	7.5	
	NUMBER AGED		30	29	20	10	3	

Species:	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE					
			I	II	III	IV	V	VI
	AVERAGE LENGTH							
	NUMBER AGED							

NOTE: *If not included in average length calculations indicate with a (*)*

APPENDIX B:

1989 Hybrid Striped Bass Management Report

CEDAR LAKE
Hybrid Striped Bass Management Report
1989

INTRODUCTION

Cedar Lake is a 781 acre natural lake located in Lake County in the extreme northwest corner of Indiana. Since the late 1940s, the lake has suffered from high bacterial counts and heavy algal blooms. Many of Cedar Lake's problems were attributed to the large number of residential units built in an area with inadequate soils for individual septic systems.

The lake's fish population was first surveyed in 1964 in an effort to provide fisheries information, along with a report by the U.S. Public Health Service and the Indiana Stream Pollution Control Board, that would be useful in formulating plans for the lake and surrounding area. The fish population in 1964 was found to be undesirable and the lake was renovated in the fall of 1966. Lake Dalecarlia, 193 acres, was also renovated at this time because of its direct connection with Cedar Lake.

Benefits of the 1966 fish eradication project were short lived. Bass, bluegill, and crappie failed to maintain populations that provided fishing acceptable to most anglers. By 1974 undesirable fish, mainly gizzard shad and carp, once again dominated the fish population accounting for more than 95% of the survey catch. The continued eutrophic state of Cedar Lake helped the undesirable fish reestablish themselves. It appeared that until the water quality of the lake improved substantially, little could be done to improve the lake's fish population. The 1974 fish survey report recommended Cedar Lake be resurveyed when the sewage system, begun in 1972, was completed. Installation of the lakewide sewage system was complete by late 1975. An additional fishery survey in 1976 again found the fish population dominated by undesirable fish.

During the winter of 1976-1977, Cedar Lake experienced a winterkill that apparently eliminated the lake's gizzard shad as no gizzard shad were collected by gill netting and electrofishing in June 1977. The 1976 report also noted that carp and shad from Cedar Creek had been observed entering Lake Dalecarlia over the dam, and subsequently entering Cedar Lake.

In 1978, the Indiana Legislature appropriated funds to determine the feasibility of restoring Cedar Lake. Indiana University began work on this project in 1979. A fishery survey was conducted by the Indiana Department of Natural Resources (DNR) to furnish current fishery information for the feasibility study. Recommendations of the Cedar Lake Restoration Feasibility Study, completed in January 1984, included:

1. Lake and watershed management practices.

2. Fish eradication - conducted by the DNR at an estimated cost of $150,000.

3. Fish restocking - conducted by the DNR.

4. Outlet improvement - to prevent rough fish from reentering Cedar Lake.

5. Alum treatment - to reduce phosphorous concentrations and suspended sediment at an estimated cost of $250,000.

6. Motorboat speed reduction - trolling speed only from ice-out to July 1 of the treatment year to prevent turbulence from disturbing the alum floc.

7. Ban on live bait fishing - to prevent the inadvertent introduction of undesirable fish into Cedar Lake.

Implementation of the above recommendation has not occurred due to the lack of funding for the Clean Lakes Program.

Cedar Lake was surveyed in 1987 to provide current information about the fish population and lake conditions. As in previous surveys since the early 1970s, undesirable species dominated the lake's fish population. It was recommended that efforts to rehabilitate Cedar Lake should continue with a reexamination of the Cedar Lake Restoration Feasibility Study by an inter-agency team representing several governmental agencies. The lake's problems are currently being reviewed as part of the Indiana Clean Lakes Program.

In an attempt to improve fishing opportunities, the Cedar Lake Chamber of Commerce stocked 4,400 hybrid striped bass (5.6 fish/acre) in August 1987. The establishment of hybrid stripers may provide additional predation in this predator poor fish population. Hybrid striped bass stocking by the DNR in 1988 was cancelled due to a shortage of fish at the state's hatcheries.

A survey consisting of 8 gill net lifts was conducted September 6 through 8, 1988 to monitor growth and survival of hybrid striped bass stocked in 1987. Forty-seven hybrids were collected ranging in length from 7.4 to 11.6 inches (5.9 fish per lift). The survey concluded that survival of the hybrid striped bass stocked in 1987 was good.

The DNR stocked an additional 7,935 hybrid striped bass (10.2 fish/acre) on June 22, 1989. These fish ranged in length from 1.3 to 1.9 inches (1.6 inch average). On October 2-3, 1989, four gill nets were run to check growth and survival of the hybrids stocked in both 1987 and 89.

RESULTS

The '89 survey catch consisted of 835 fish representing 10 species. Relative abundance of the major species by number was: yellow perch 73%, carp 12%, gizzard shad 6%, hybrid striped bass 4%, and black crappie 3%.

Thirty-five hybrid striped bass were collected that ranged in length from 6.0 to 8.5 inches. All hybrids collected were age O+ fish from the 1989 stocking. The average hybrid was 7.5 inches long and weighed .18 pounds. Hybrid striped bass were collected at the rate of 8.75 fish per net lift.

Yellow perch were the most abundant fish collected. The 613 perch collected ranged in length from 6.1 to 8.1 inches. Perch were collected at the rate of 153.3 fish per lift in 1989 compared to 35.1 fish per lift in 1988.

Gizzard shad were the third most abundant fish collected in 1989. They were collected at the rate of 13.3 fish per lift compared to 35 per lift in 1988.

DISCUSSION

Although it was disappointing not to find any two year old hybrids from the 1987 stocking, survival and growth of hybrids stocked in 1989 was good.

RECOMMENDATIONS

Continued hybrid bass stocking and periodic evaluations by gill netting are recommended.

Submitted by: Bob Robertson, Fisheries Biologist
Date: 2/13/90

Approved by: Gary Hudson
Gary Hudson, Fisheries Supervisor
Date: 2/26/90

SAMPLING EFFORT

ELECTROFISHING	Day hours	Night hours	Total hours
TRAPS	Number of traps	Hours	Total hours
GILL NETS	Number of nets 4	Hours 24	Total hours 96

PHYSICAL AND CHEMICAL CHARACTERISTICS

Color Green	Turbidity 1 Feet 1 Inches (SECCHI DISK)

TEMPERATURE

DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°
SURFACE	59.0	40		80	
2	59.0	42		82	
4	59.0	44		84	
6	59.0	46		86	
8	59.0	48		88	
10	59.0	50		90	
12	58.0	52		92	
14	58.0	54		94	
16		56		96	
18		58		98	
20		60		100	
22		62			
24		64			
26		66			
28		68			
30		70			
32		72			
34		74			
36		76			
38		78			

DISSOLVED OXYGEN (D.O.) - TOTAL ALKALINITY - pH

DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	Comments:
SURFACE	10.2	68	9.5	45				
5	10.0			50				
10	9.2			55				
15	4.0			60				
20				65				
25				70				
30				75				
35				80				
40								

*ppm = parts per million

CEDAR LAKE 1989

SPECIES AND RELATIVE ABUNDANCE OF FISHES COLLECTED BY NUMBER AND WEIGHT

*COMMON NAME OF FISH	NUMBER	PERCENT	LENGTH RANGE (Inches)	WEIGHT (Pounds)	PERCENT
Yellow perch	613	73.4	6.1 - 8.1		
Carp	97	11.6	9.8 - 17.7		
Gizzard shad	53	6.3	4.2 - 13.6		
Hybrid striped bass	35	4.2	6.0 - 8.5	6.42	
Black crappie	21	2.5	3.6 - 8.5		
Goldfish	11	1.3	10.7 - 14.1		
Black bullhead	2	0.2	7.5 - 8.6		
Channel catfish	1	0.1	22.7		
White crappie	1	0 1	6.7		
Pumpkinseed	1	0.1	4.1		
Total	835				

*Common names of fishes recognized by the American Fisheries Society

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* HYBRID STRIPED BASS

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0					15.5				
2.5					16.0				
3.0					16.5				
3.5					17.0				
4.0					17.5				
4.5					18.0				
5.0					18.5				
5.5					19.0				
6.0	1	2.9	.10	0+	19.5				
6.5	2	5.7	.13	0+	20.0				
7.0	13	37.1	.15	0+	Total	35			
7.5	8	22.9	.18	0+					
8.0	9	25.7	.22	0+					
8.5	2	5.7	.27	0+					
9.0									
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									

ELECTROFISHING CATCH		GILL NET CATCH	35	TRAP NET CATCH	